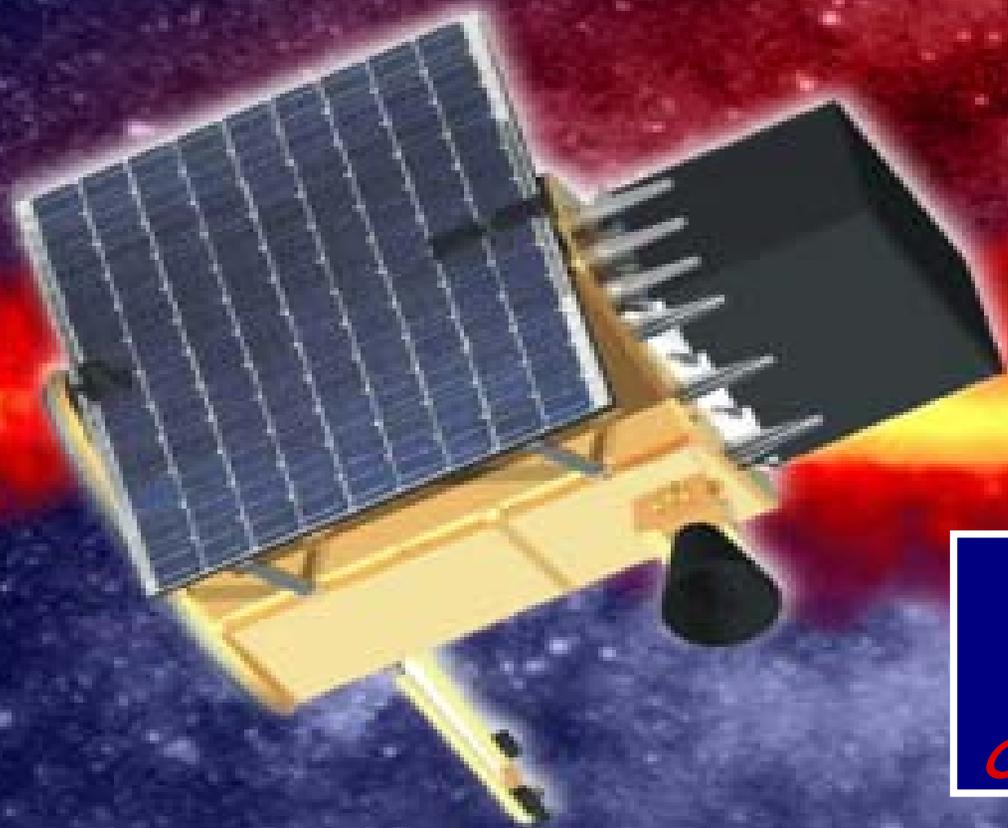


agile

Astro rivelatore Gamma a Immagini Leggero



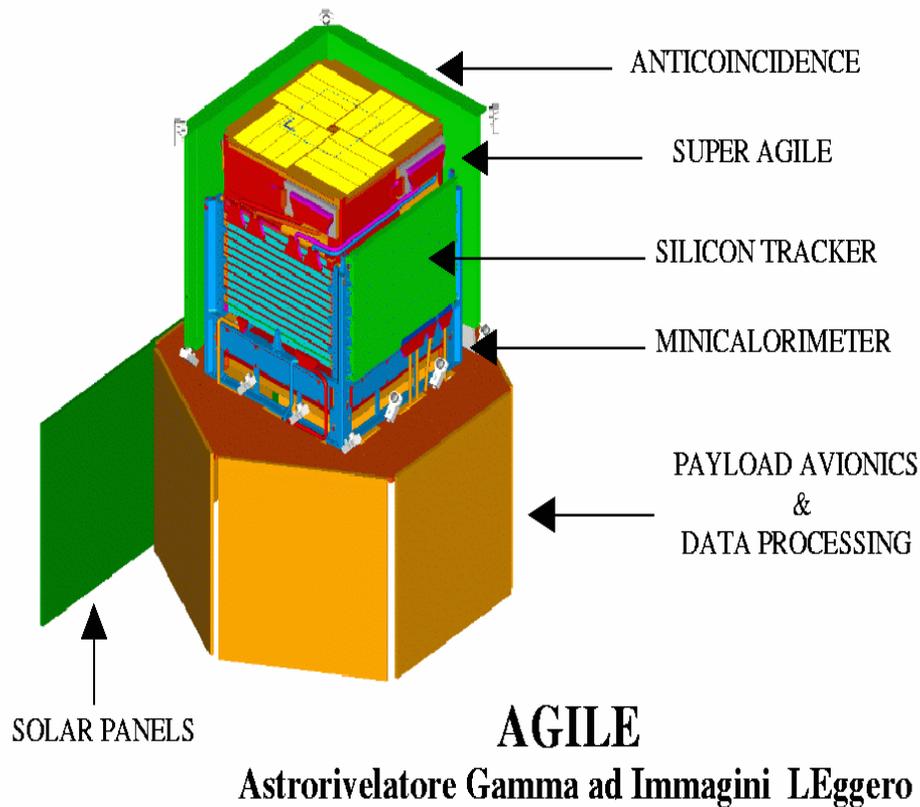
Andrea Giuliani

IASF sez. Milano - INAF

On behalf of the AGILE Team

Astorivelatore **G**amma a **I**mmagini **LE**ggero

AGILE



An **ASI - INAF - INFN** satellite for **X** and **hard γ** astronomy

Launch in the **2006** by the **Indian Space Research Organization**

Total satellite mass :

~ **350 kg**

(Small Explorer -SMEX class)

Astorivelatore **G**amma a **I**mmagini **LE**ggero

AGILE



SuperAGILE :

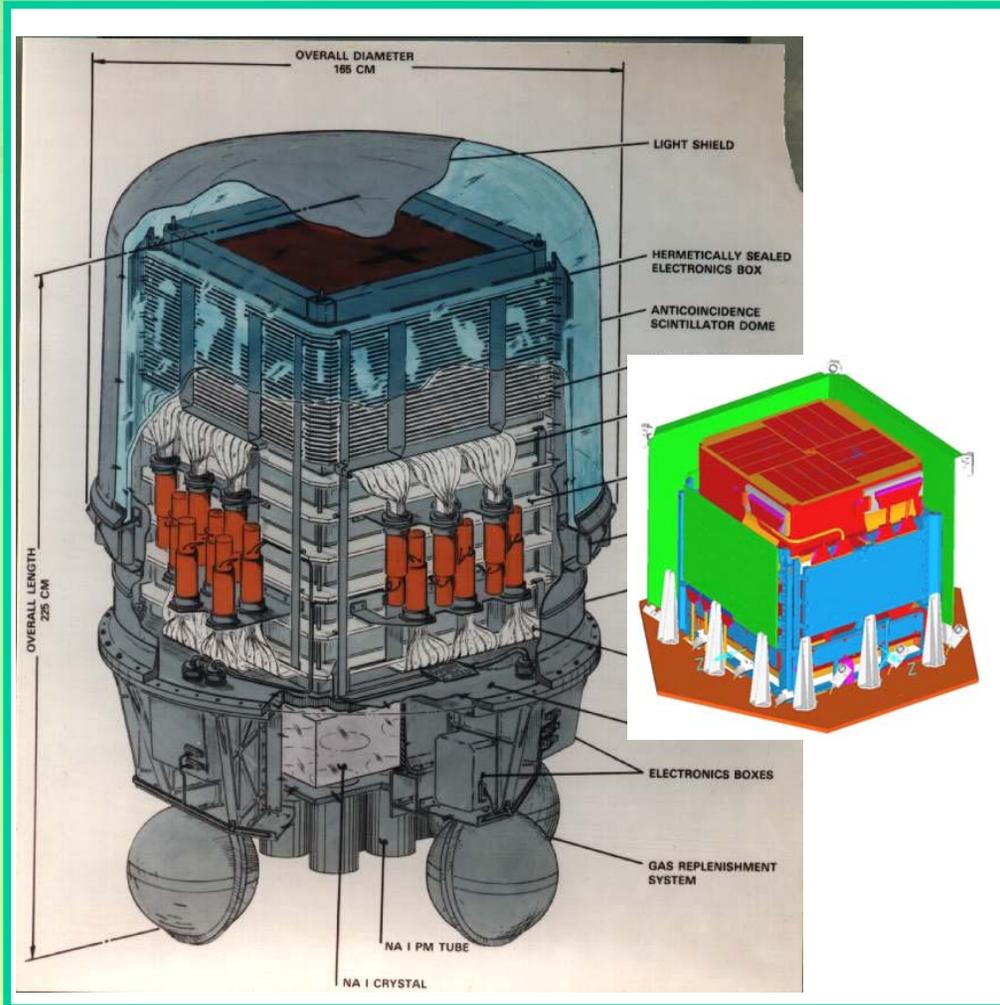
- Ultra-light coded mask
- 15 - 40 keV

GRID instrument :

- Si tracker + CsI calorimeter
- 30 MeV - 50 GeV
- Optimal PSF
- Large FOV (2.5 sr)

Scientific Instrument
mass: **120 kg (!)**

Astorivelatore Γ amma a Immagini LE ggero



SuperAGILE :

- Ultra-light coded mask
- 15 - 40 keV

GRID instrument :

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Summary of the Presentation

(1) Hardware

- GRID
- SuperAGILE
- AntiCoincidence

(2) Scientific Software

- Hits to photons
- Photons to sources

(3) Science

- AGN
- Pulsars
- GRB
- UnID Sources
- Diffuse Galactic Emission

(4) Present Status

Summary of the Presentation

(1) Hardware

- GRID
- SuperAGILE
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(2) Scientific Software

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- Photons to sources

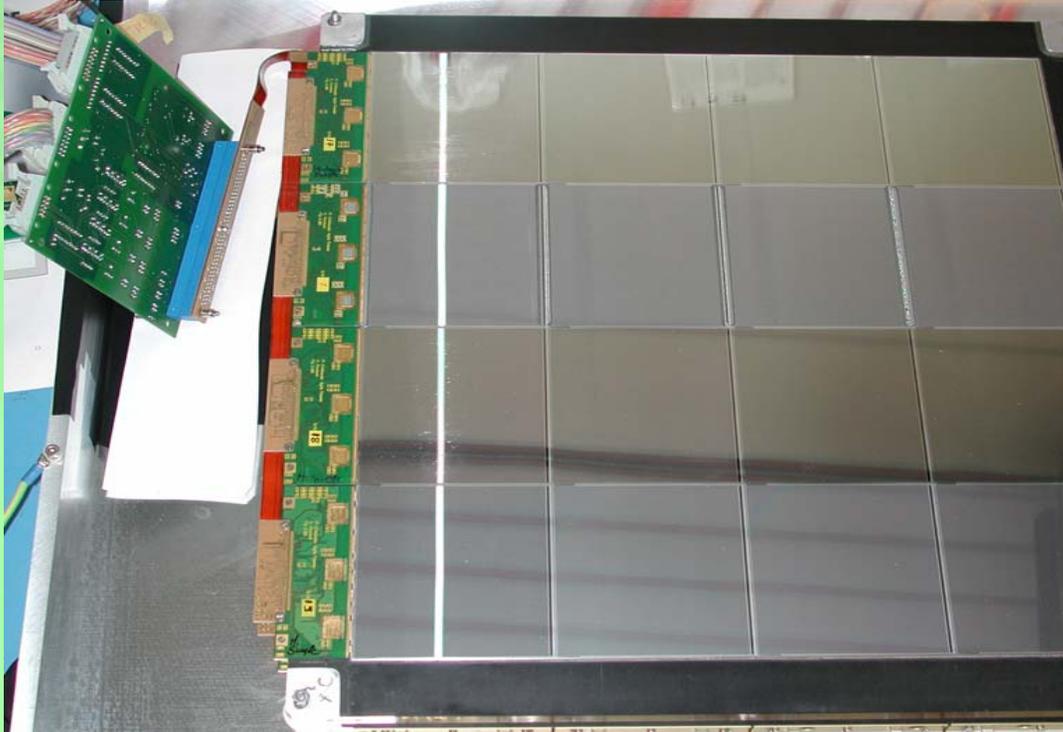
(3) Science

- AGN
- Pulsars
- GRB
- UnID Sources
- Diffuse Galactic Emission

(4) Present Status



W-Si Tracker



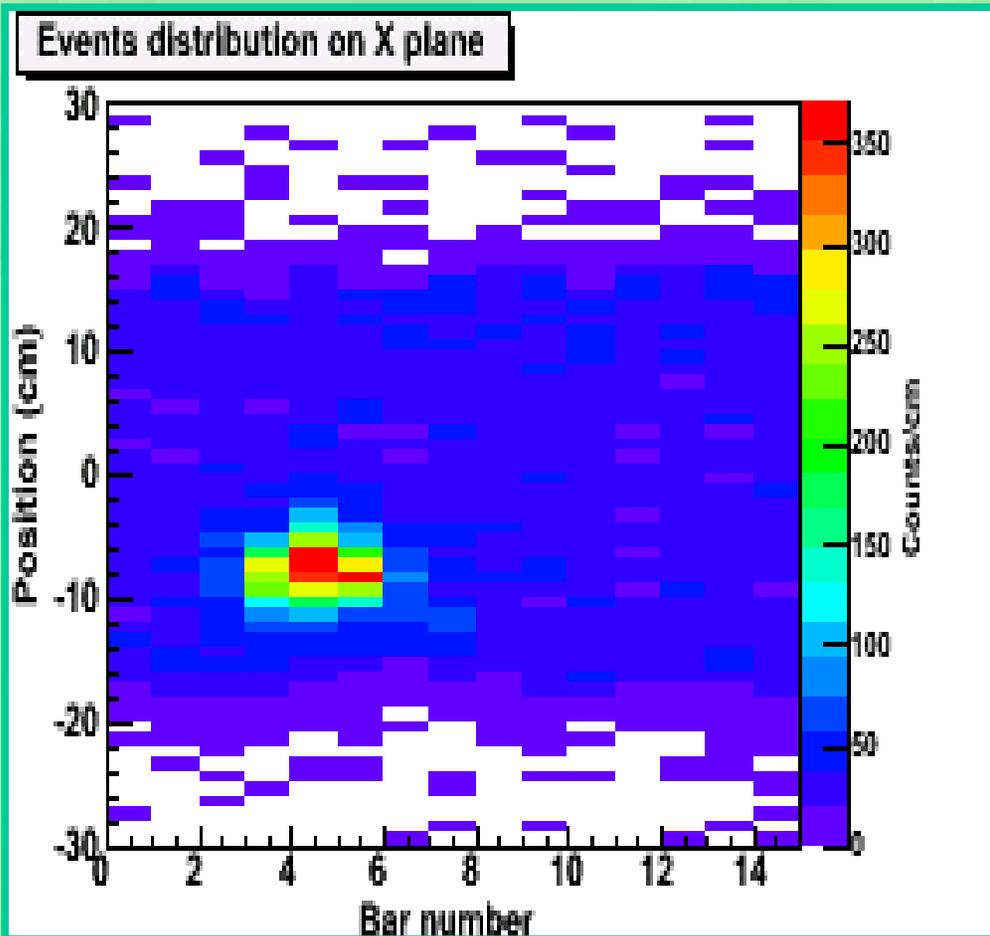
- 12 planes with :
- W converter
($0.07 X_0$)
 - Si microstrip
(pitch $121 \mu\text{m}$)

Spatial Resolution:
 $40 \mu\text{m}$

The AGILE Silicon Tracker developed
by INFN Trieste.
In the MIPOT laboratories before being
delivered to LABEN on June 30, 2005.

Total thickness:
 $0.8 X_0$

MiniCalorimetro



The **AGILE MiniCalorimetro** developed by IASF Bologna (INAF) and LABEN.

Thickness : **$1.5 X_0$**

30 **CsI** bars on 2 layers,
60 readout channels

Energy range : **300 keV - 100 MeV** (GRID mode)

Energy resolution : **13% @ 1 MeV** (single bar)

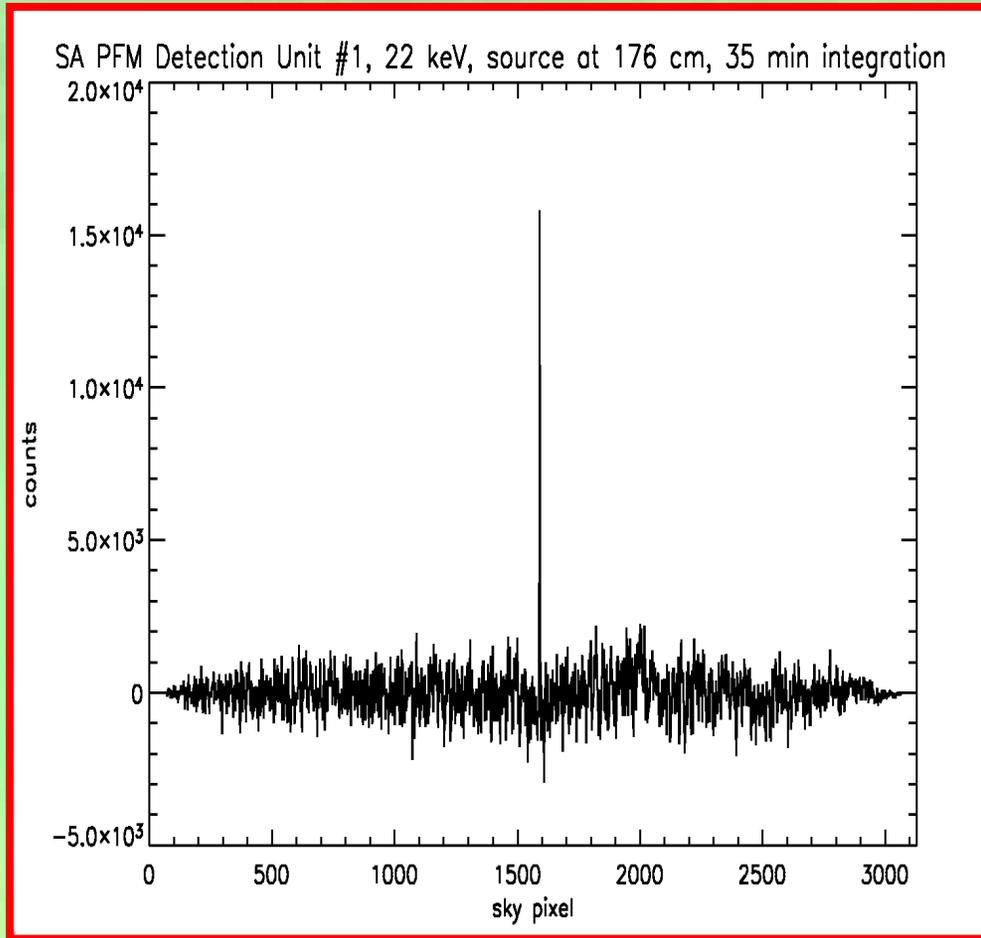
Independent **GRB** search

Effective area : **400 cm^2**

Energy range : **400 KeV -10 MeV**

Field of View : **$4 \pi \text{ sr}$**

SuperAGILE



SuperAGILE developed by IASF Roma
(INAF).

Detector : 410 μm Silicon
microstrips, 121 μm pitch, 1D
position sensitive

Energy range : 15 - 40 keV

Geometric Area : 1444 cm^2

Effective Area : $\sim 300 \text{ cm}^2$ (on
axis, 13 keV)

Energy Resolution : 7-8 keV

Angular Resolution : 6 arcmin

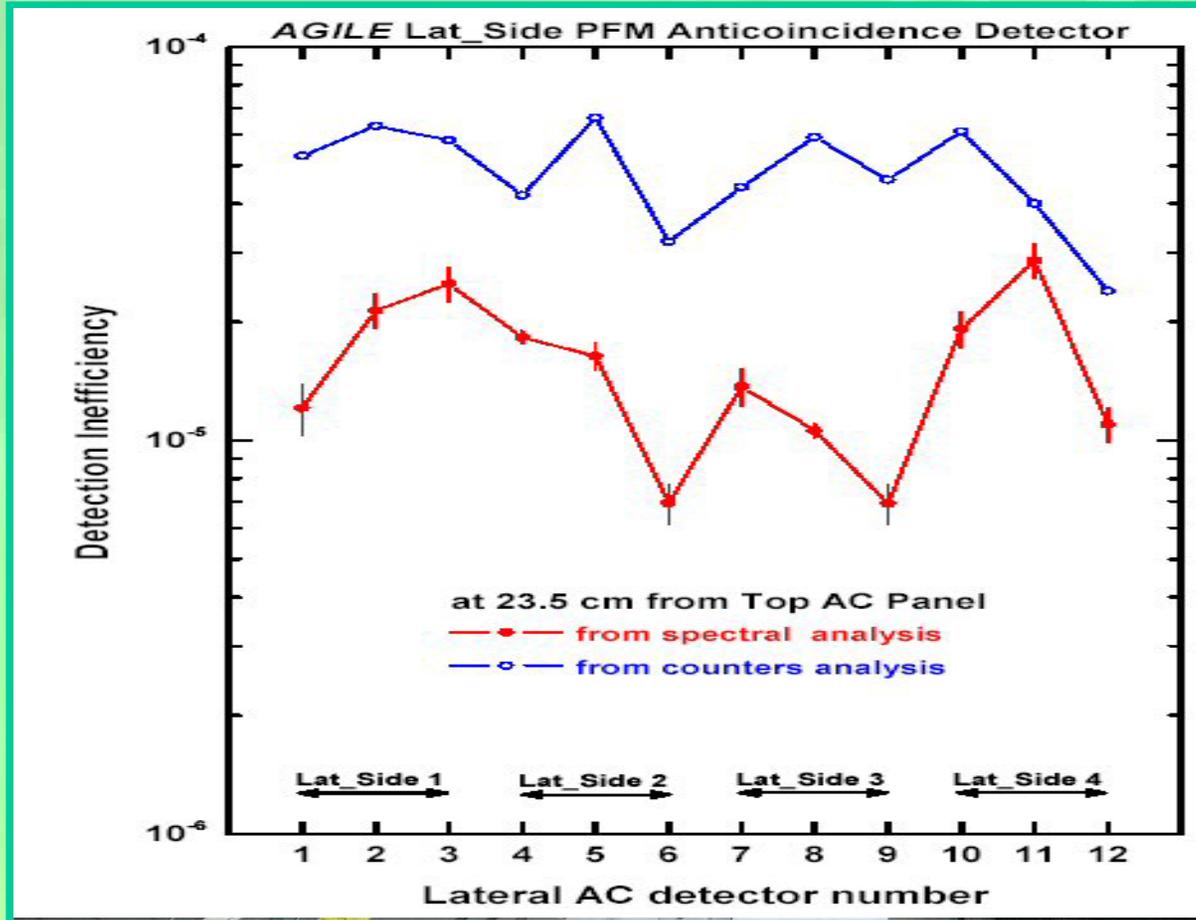
Source location Accuracy : 1.5
arcmin for bright sources

FOV : $2 \times (107 \times 68) \text{ deg}^2$ FWZR

Timing Accuracy : $\sim 5 \mu\text{s}$

Sensitivity : $\sim 12 \text{ mCrab}$ (50ks,
on axis)

Anticoincidence System



The AGILE Anticoincidence System developed by **IASF Milano** (INAF) during the vibration test campaign (January 2005).

Summary of the Presentation

(1) Hardware

- GRID
- SuperAGILE
- AntiCoincidence

(2) Scientific Software

- Hits to photons
- Photons to sources

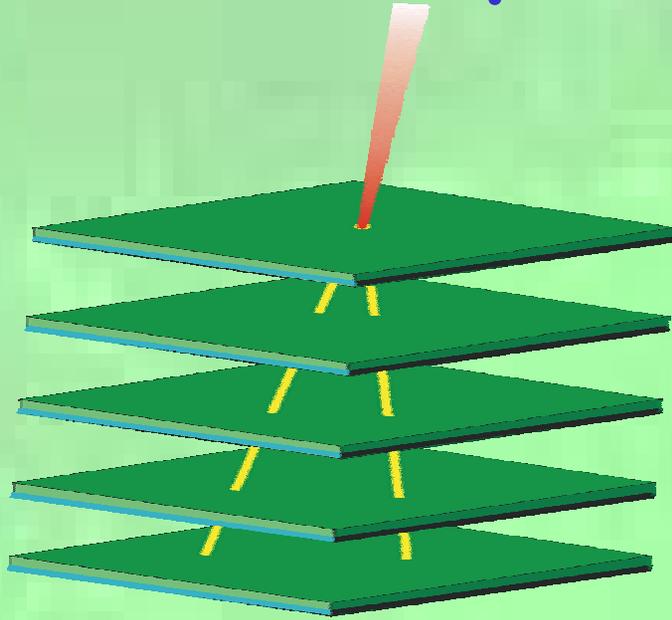


(3) Science

- AGN
- Pulsars
- GRB
- UnID Sources
- Diffuse Galactic Emission

(4) Present Status

Detection in pair production telescopes

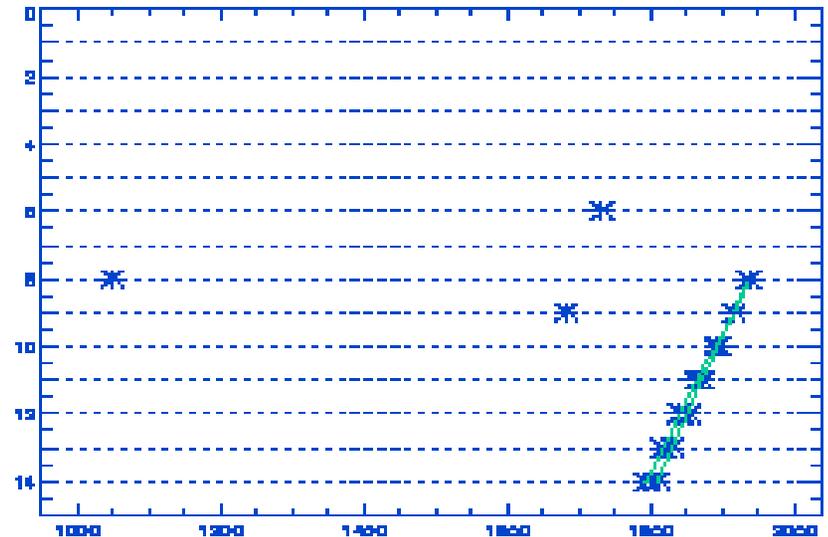
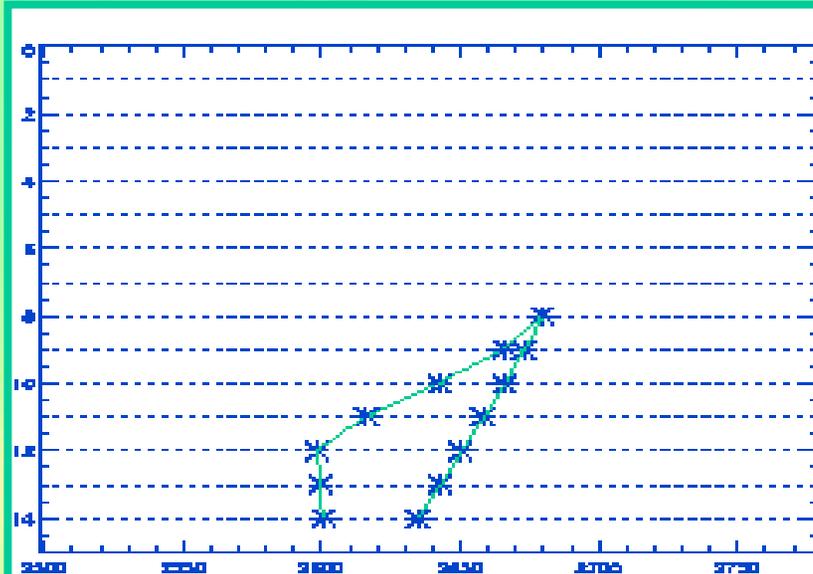


$$\gamma \rightarrow e^+e^-$$

conserve p and E

but:

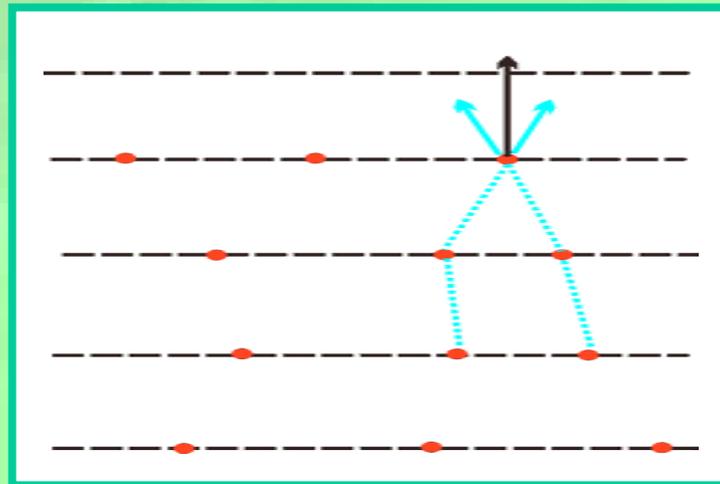
- Only projection information
- Multiple Scattering
- Noise hits



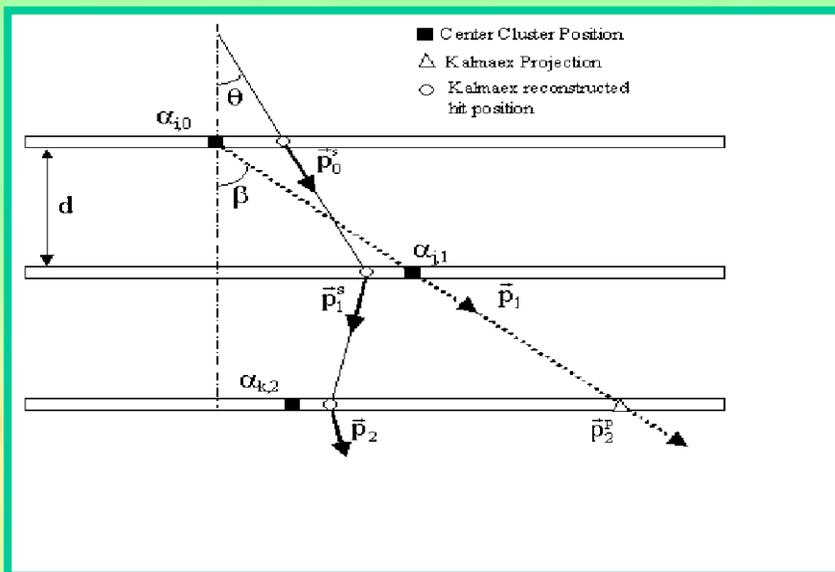
Track reconstruction

The 3 steps of tracks reconstruction :

- Finding the tracks
- Fitting the tracks
- e^+e^- to gamma



Kalman Filter

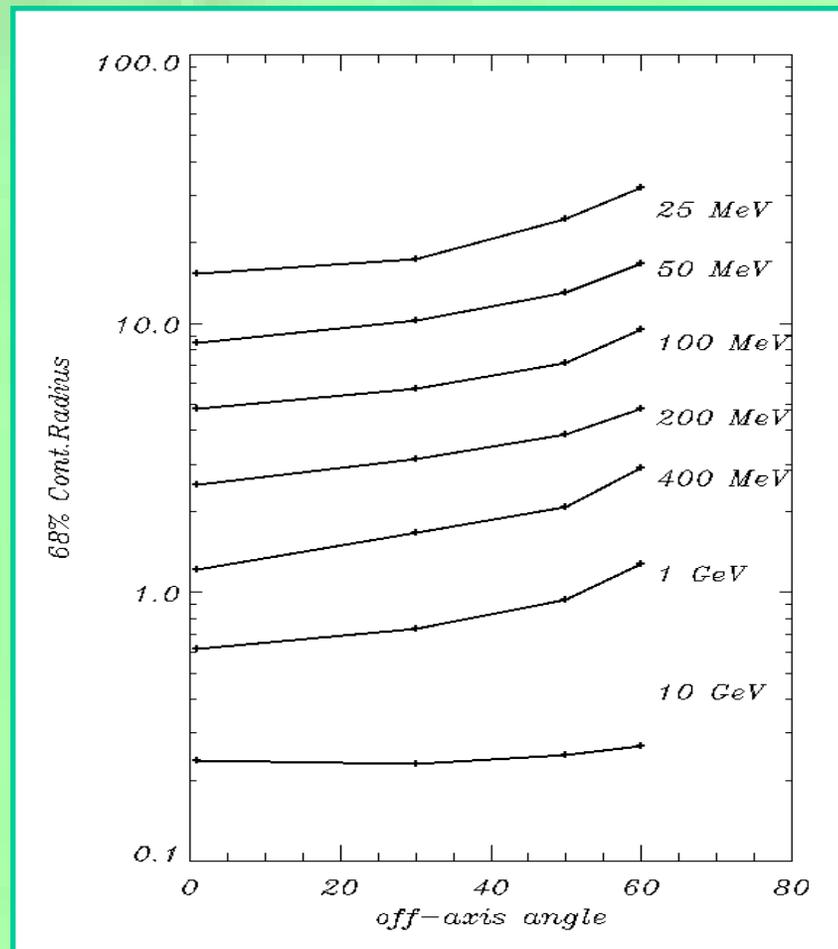
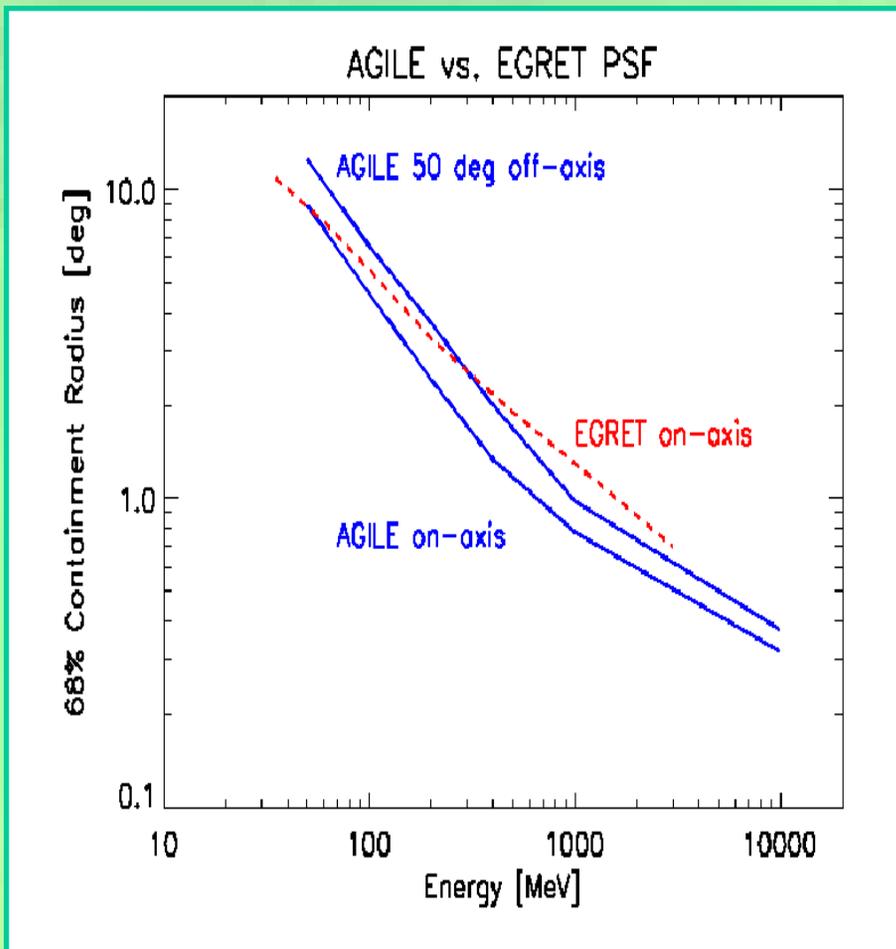


• Few operations required (find, fit)

• Takes into account the MS

For the first time on-board !

GRID performances: Angular resolution



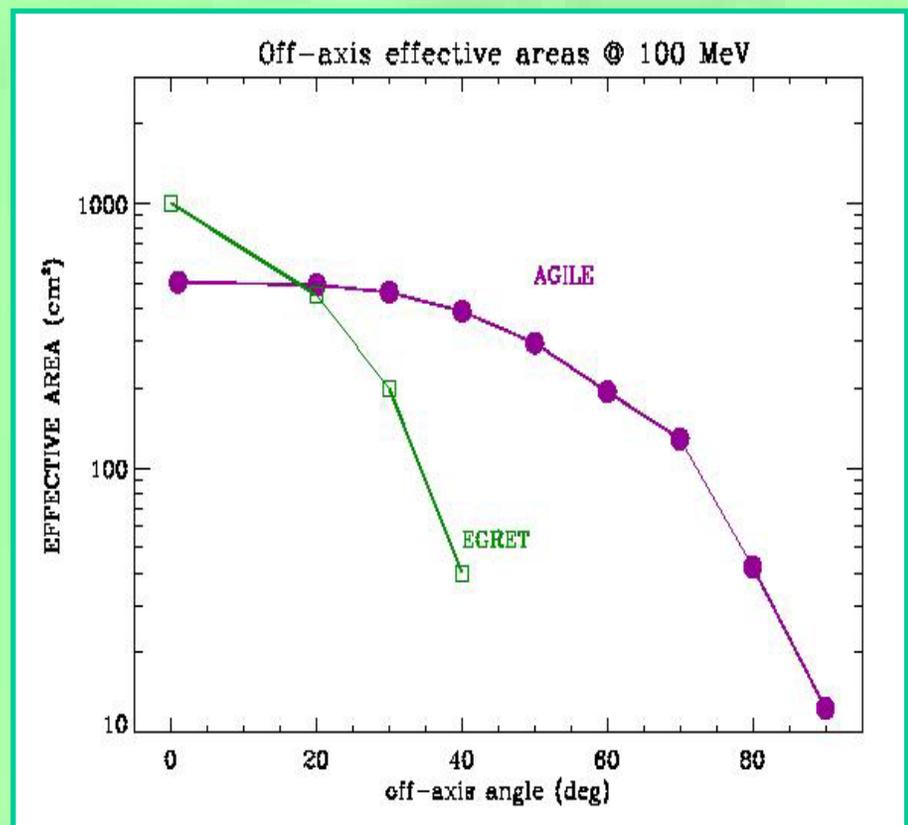
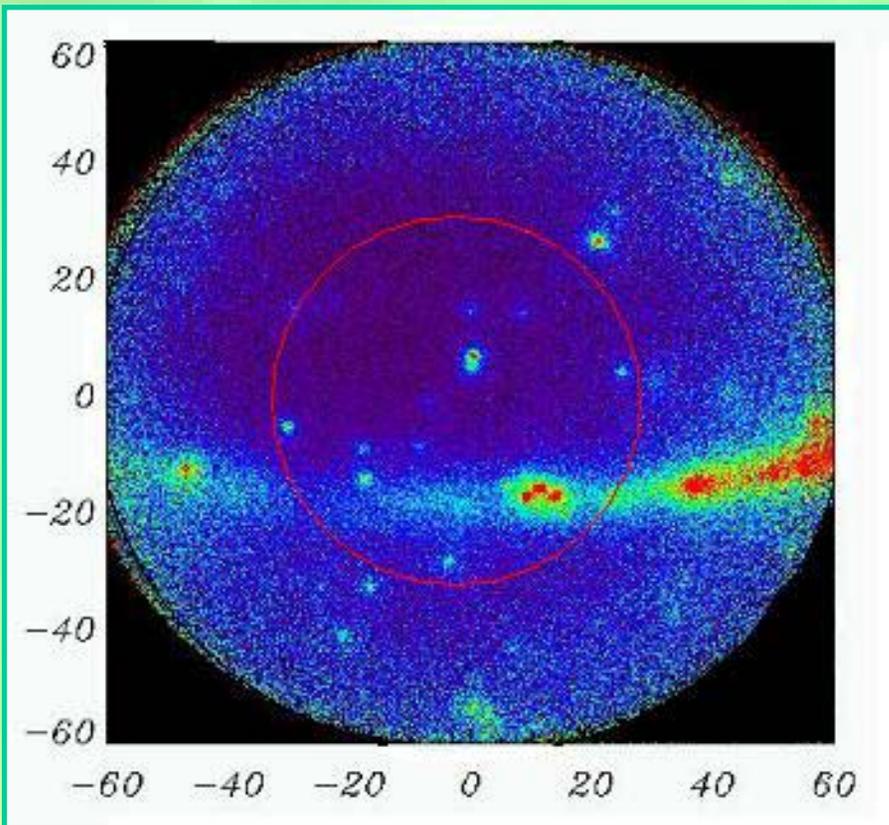
2 times better than EGRET

Weak dependence on off-axis angle

GRID performances: field of view

Field of view: ~ 3 sr

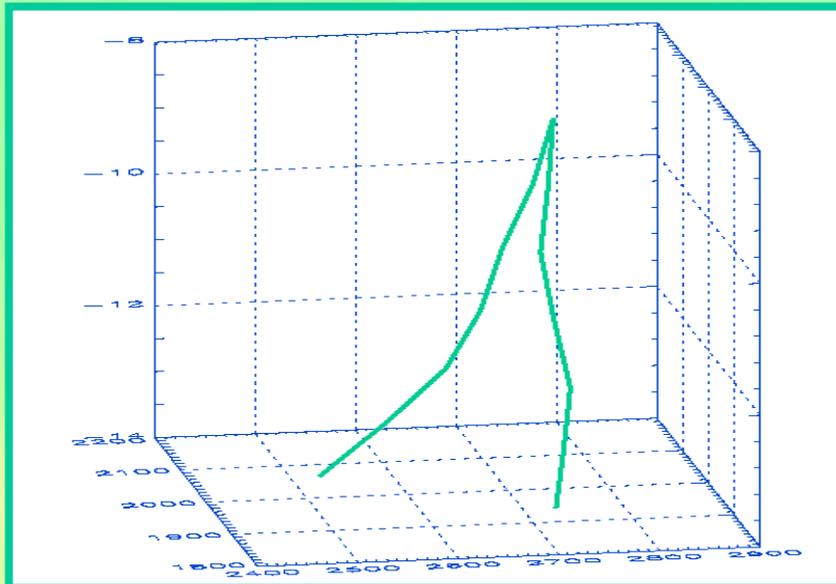
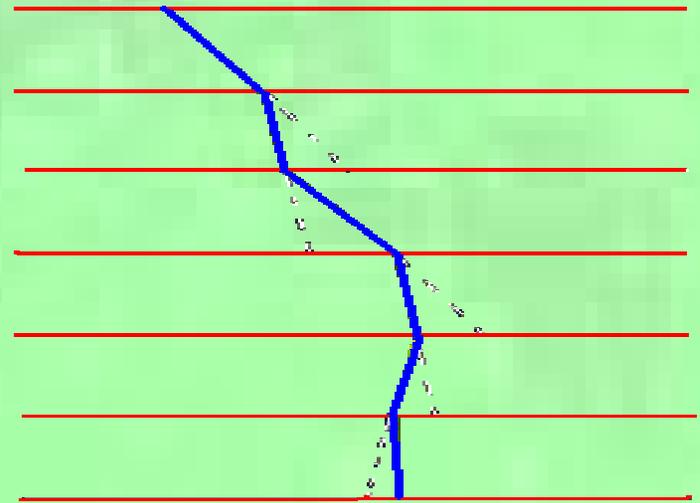
Off-axis
Effective Area



Photon Energy Measurement

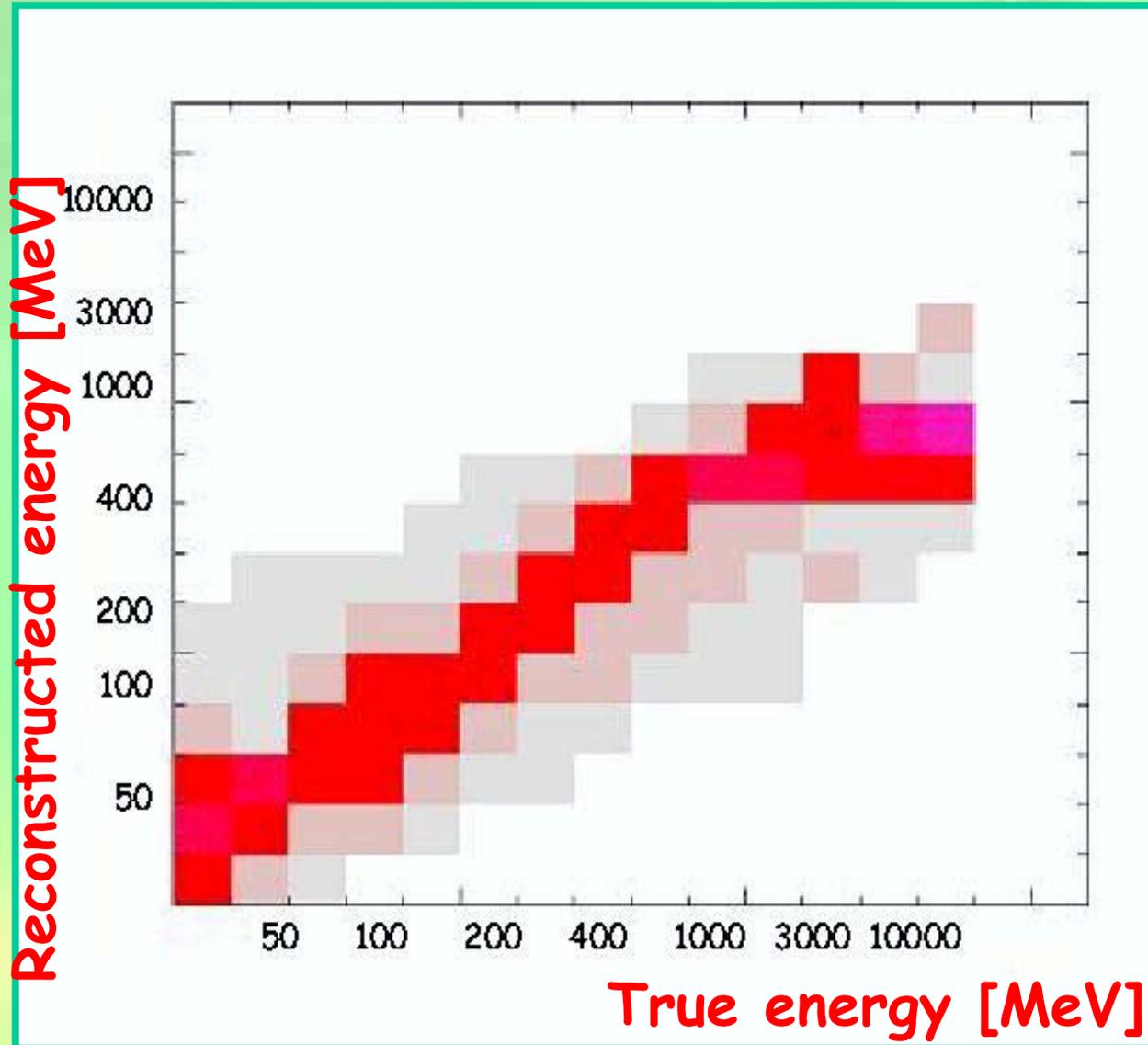
Moliere formula :

$$\theta_{rms} = \frac{13.6}{E_c[MeV]} \sqrt{\frac{z}{X_0}} \left(1 + 0.038 \ln \frac{z}{X_0} \right)$$



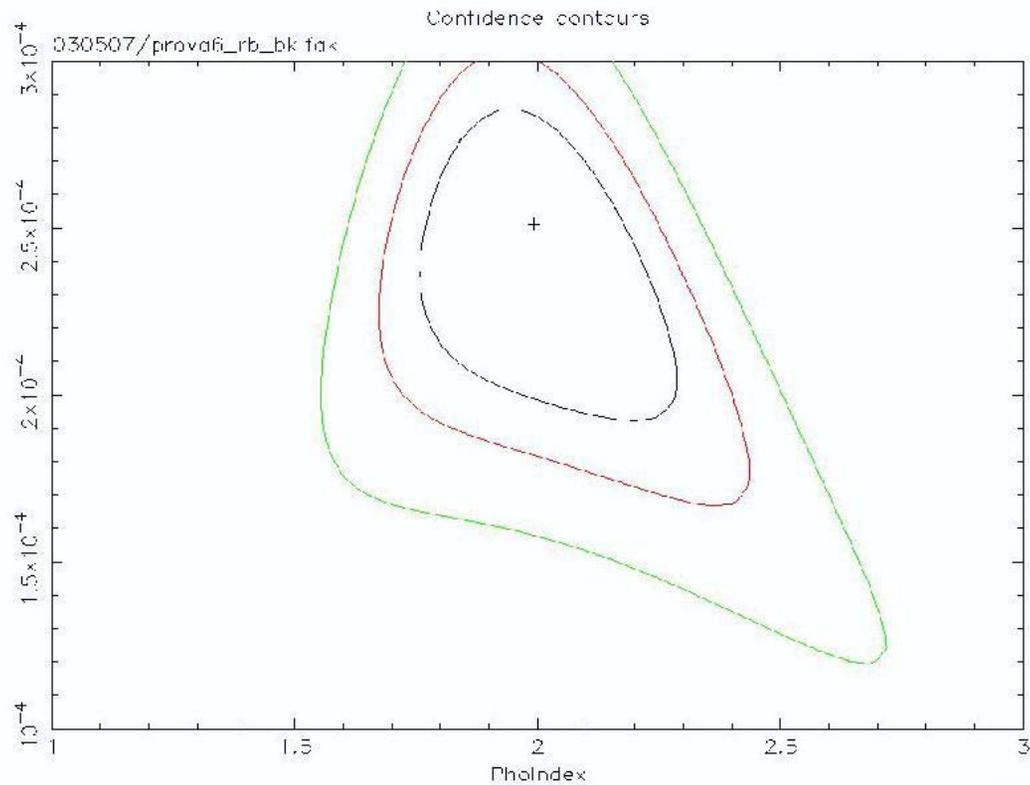
- Measure of MS angles along the track and crossed thickness
- Three-dimensional track reconstruction
- Energy loss (bremsstrahlung and ionization)

GRID Response Matrix

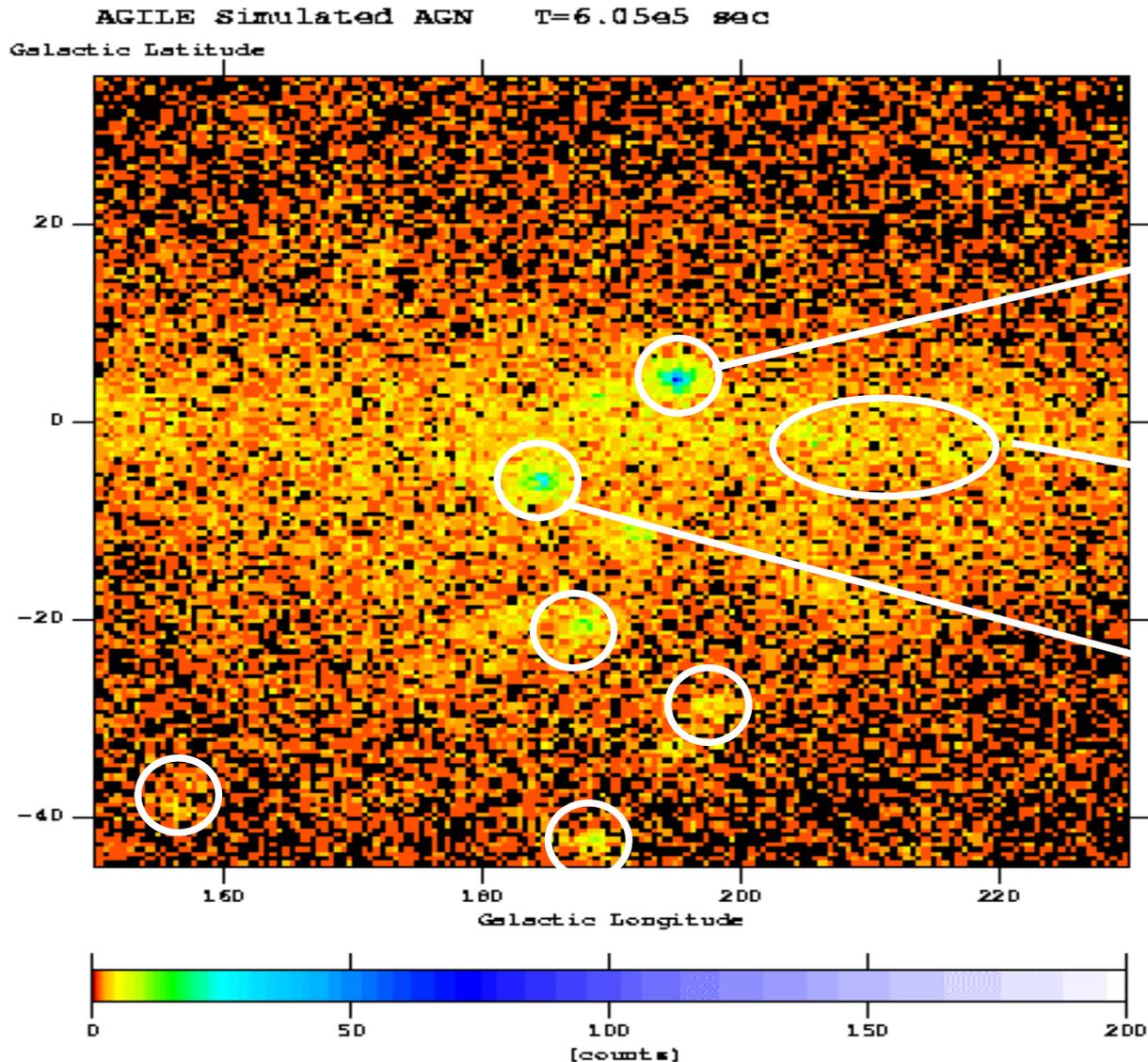


Combining
informations
from both
Tracker and
MiniCalorimetro

Spectral resolution



AGILE's counts map



Geminga PSR
($F \sim 230 \cdot 10^{-8}$)

Galactic diff.
emission

Crab PSR
($F \sim 350 \cdot 10^{-8}$)

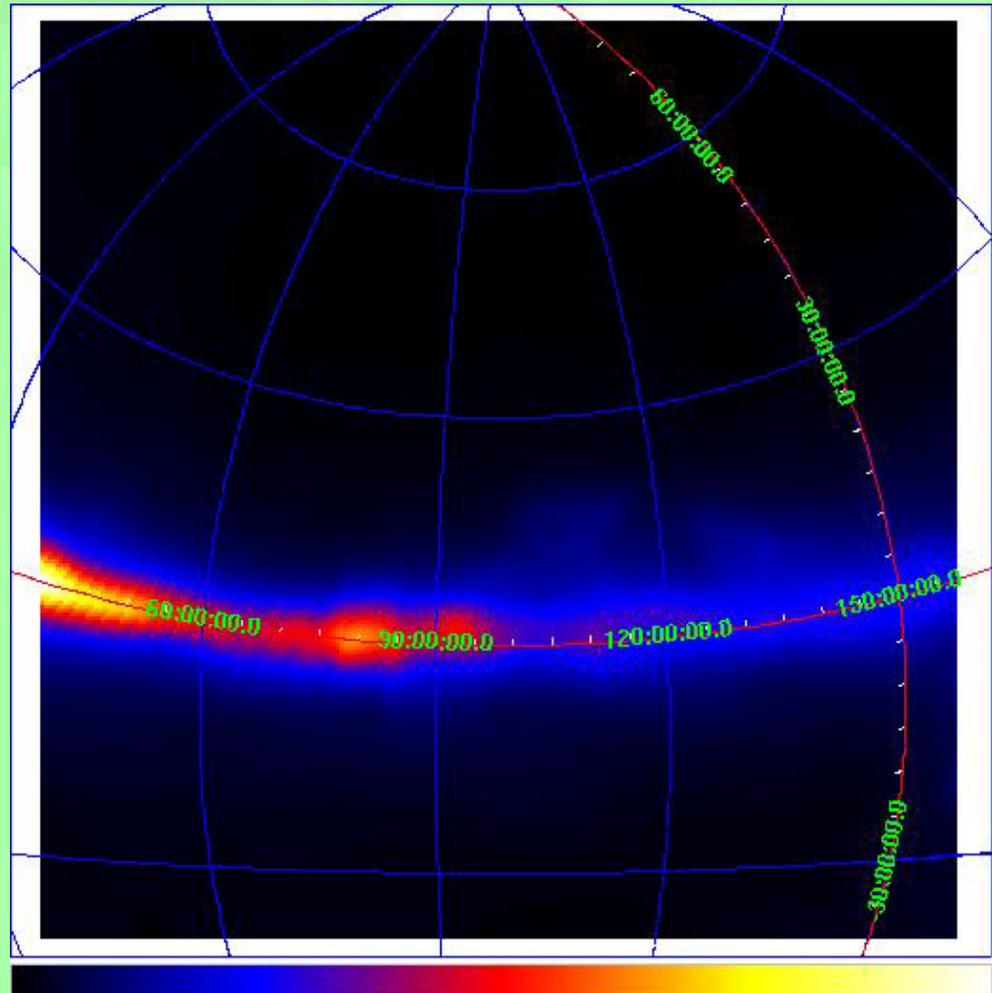
AGILE's diffuse emission map

Diffuse model is :

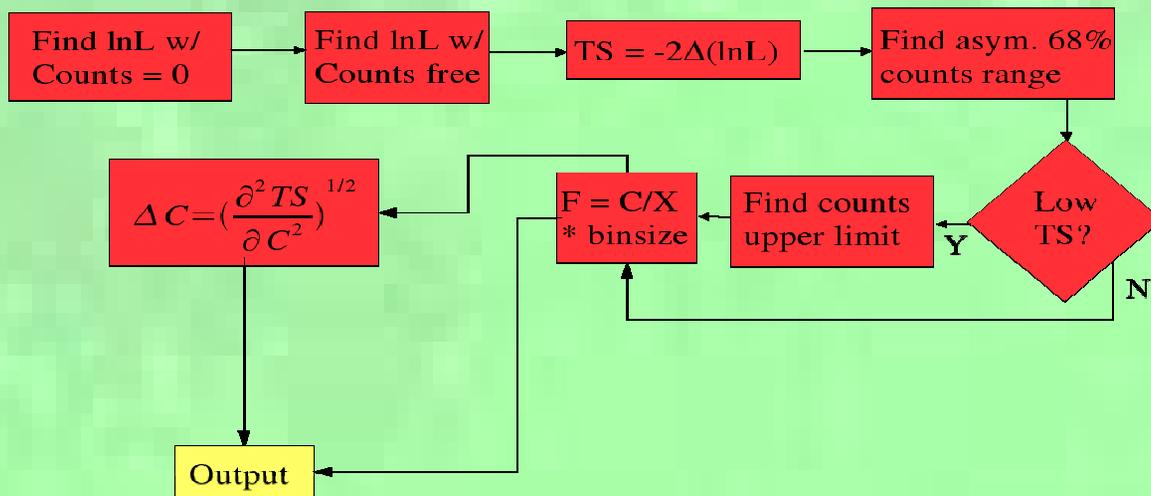
convolved with point spread function

summed over energy weighted by spectrum

binned according to projection used by counts and exposure maps



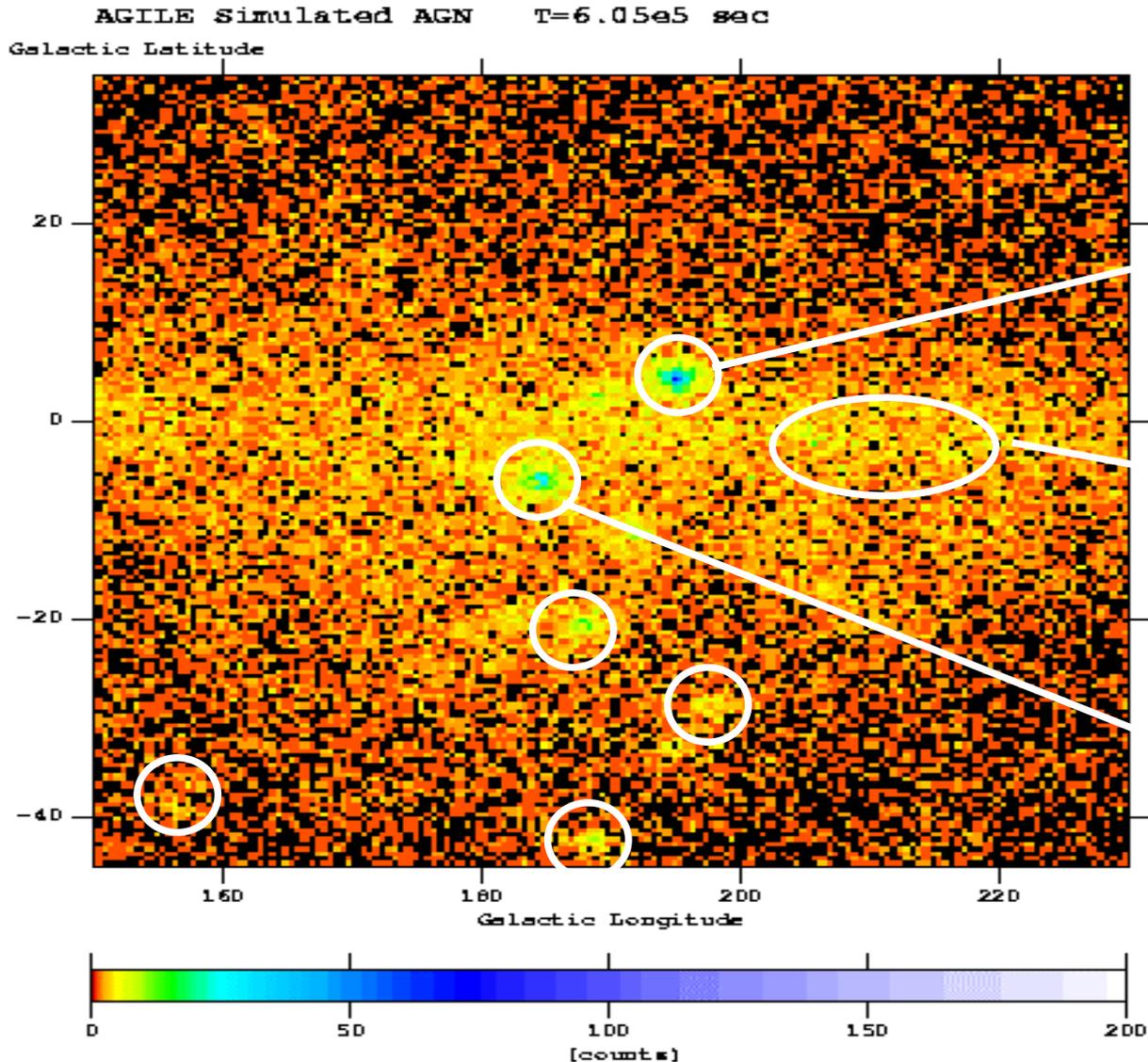
AGILE's Likelihood Data Processing



$2 * \log(\text{likelihood with source} / \text{likelihood without sources})$
-> Test Statistic = source significance²

Source coefficient : counts / exposure = flux

AGILE's counts map



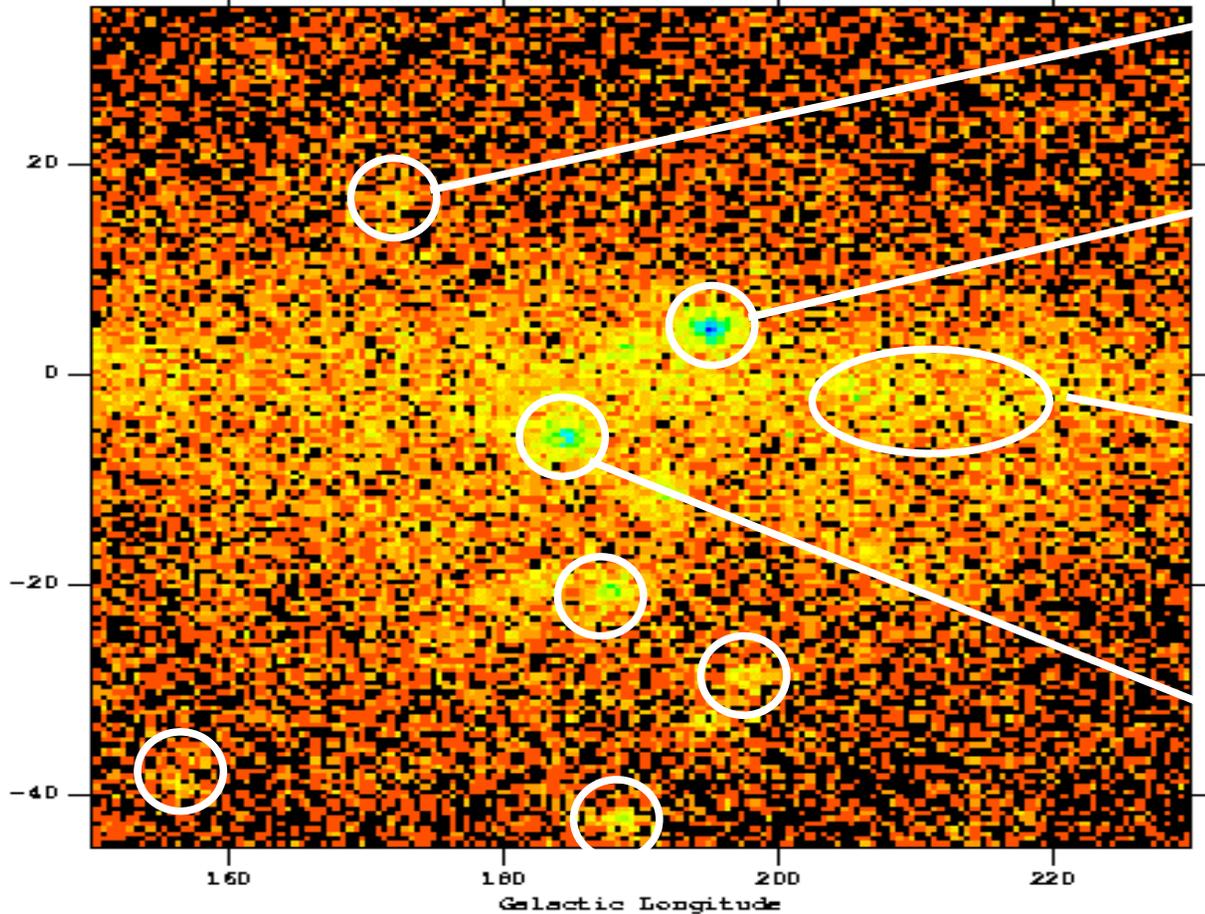
Geminga PSR
($F \sim 230 \cdot 10^{-8}$)

Galactic diff.
emission

Crab PSR
($F \sim 350 \cdot 10^{-8}$)

AGILE's counts map

AGILE Simulated AGN T=6.05e5 sec l=172.0 b=17.0
Galactic Latitude



New Source !
($F \sim 30 \cdot 10^{-8}$)

Geminga PSR
($F \sim 230 \cdot 10^{-8}$)

Galactic diff. emission

Crab PSR
($F \sim 350 \cdot 10^{-8}$)

AGILE's simulated point source location

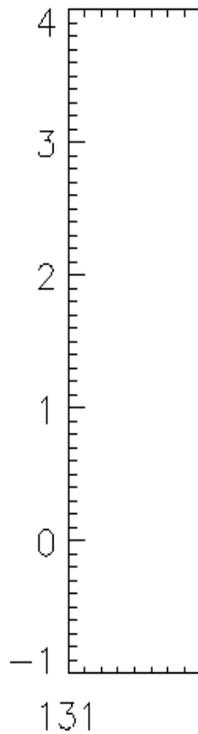
Comparison with EGRET

3EG J0241+6103

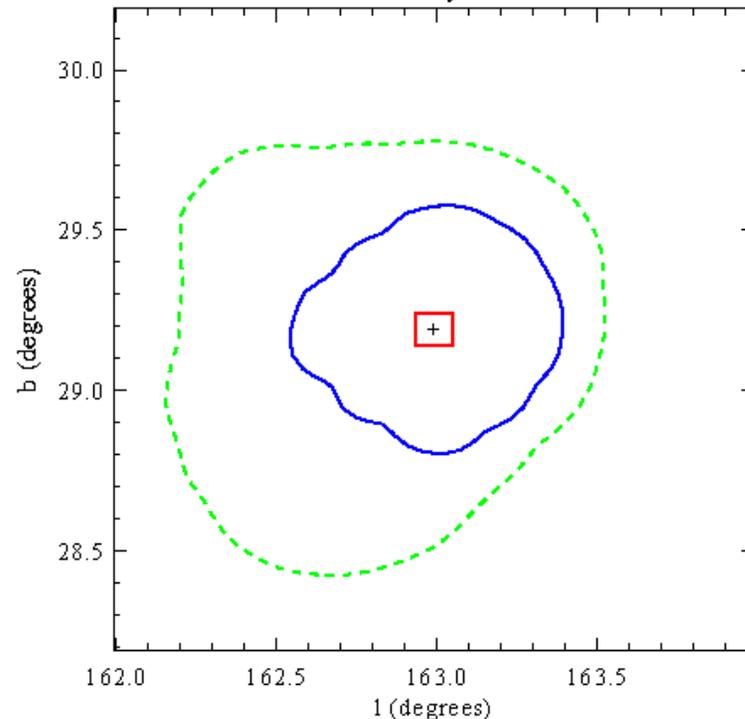
3EG J0229+6151

B (deg)

B (deg)

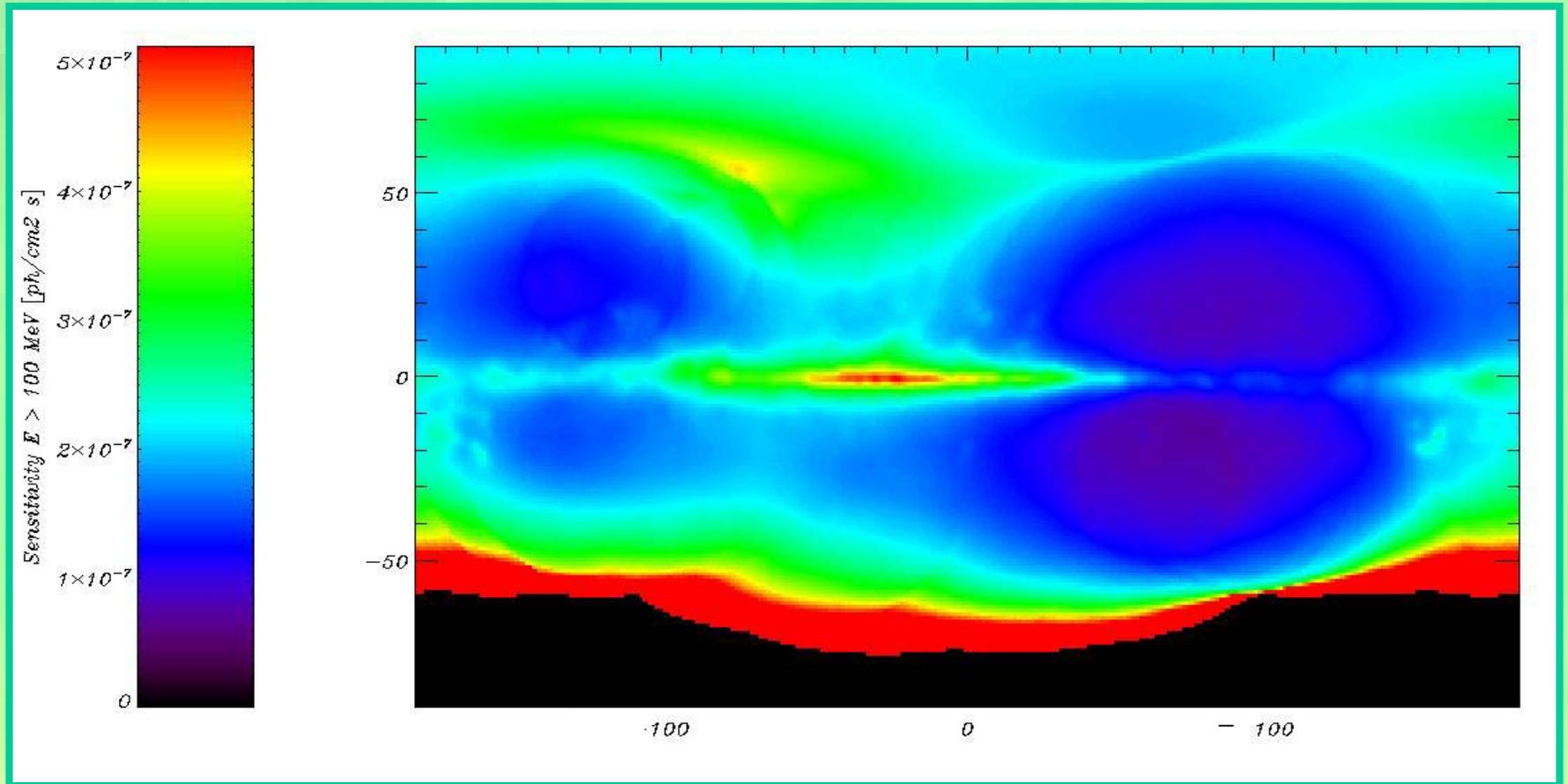


Source Location Accuracy - AGN 95% Contours



AGILE a, b = 22.8, 20.9 arcmin EGRET a, b = 41.5, 36.4 arcmin SuperAGILE a = 6.0 arcmin

AGILE's sensitivity



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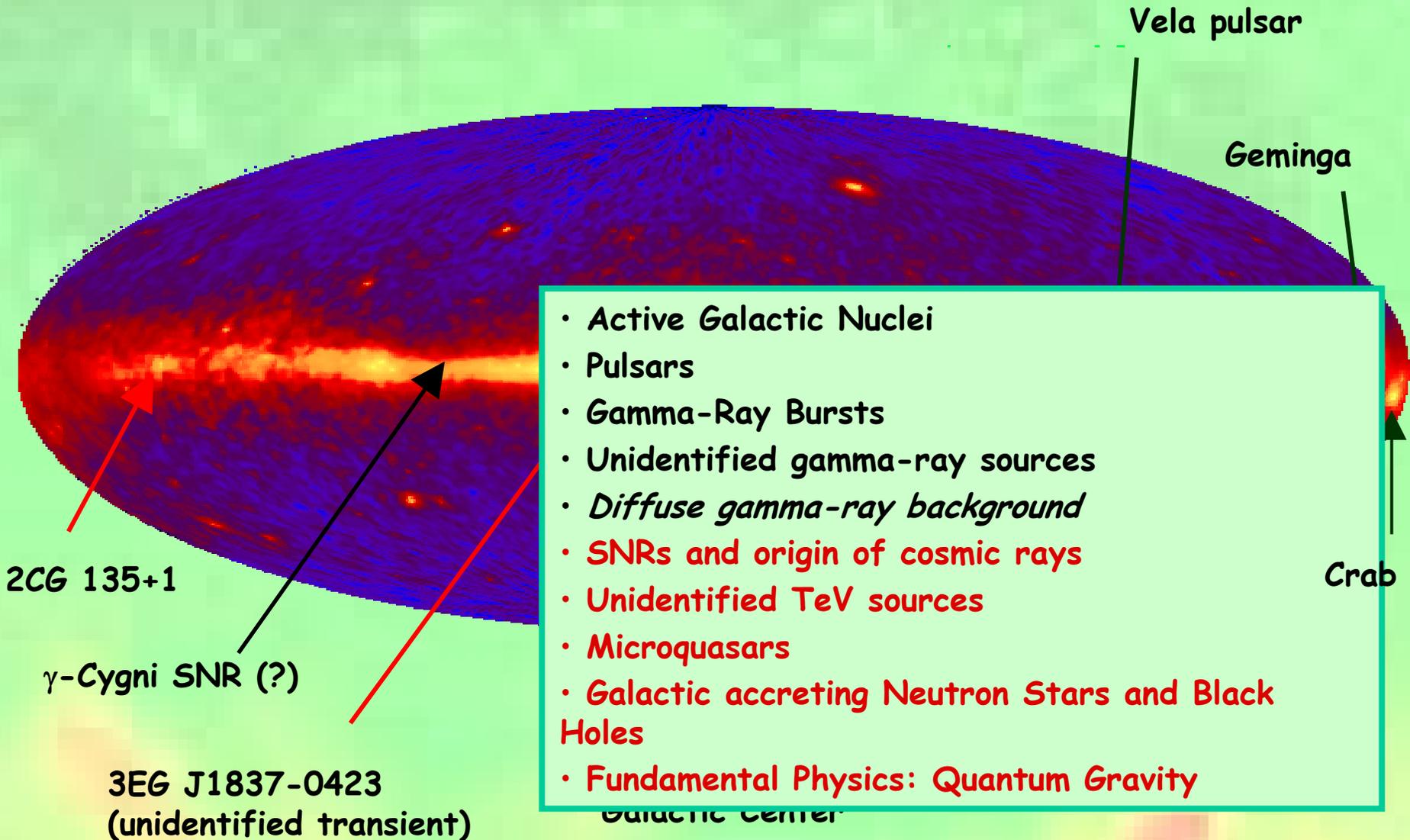
(3) Science

- AGN
- Pulsars
- GRB
- UnID Sources
- Diffuse Galactic Emission

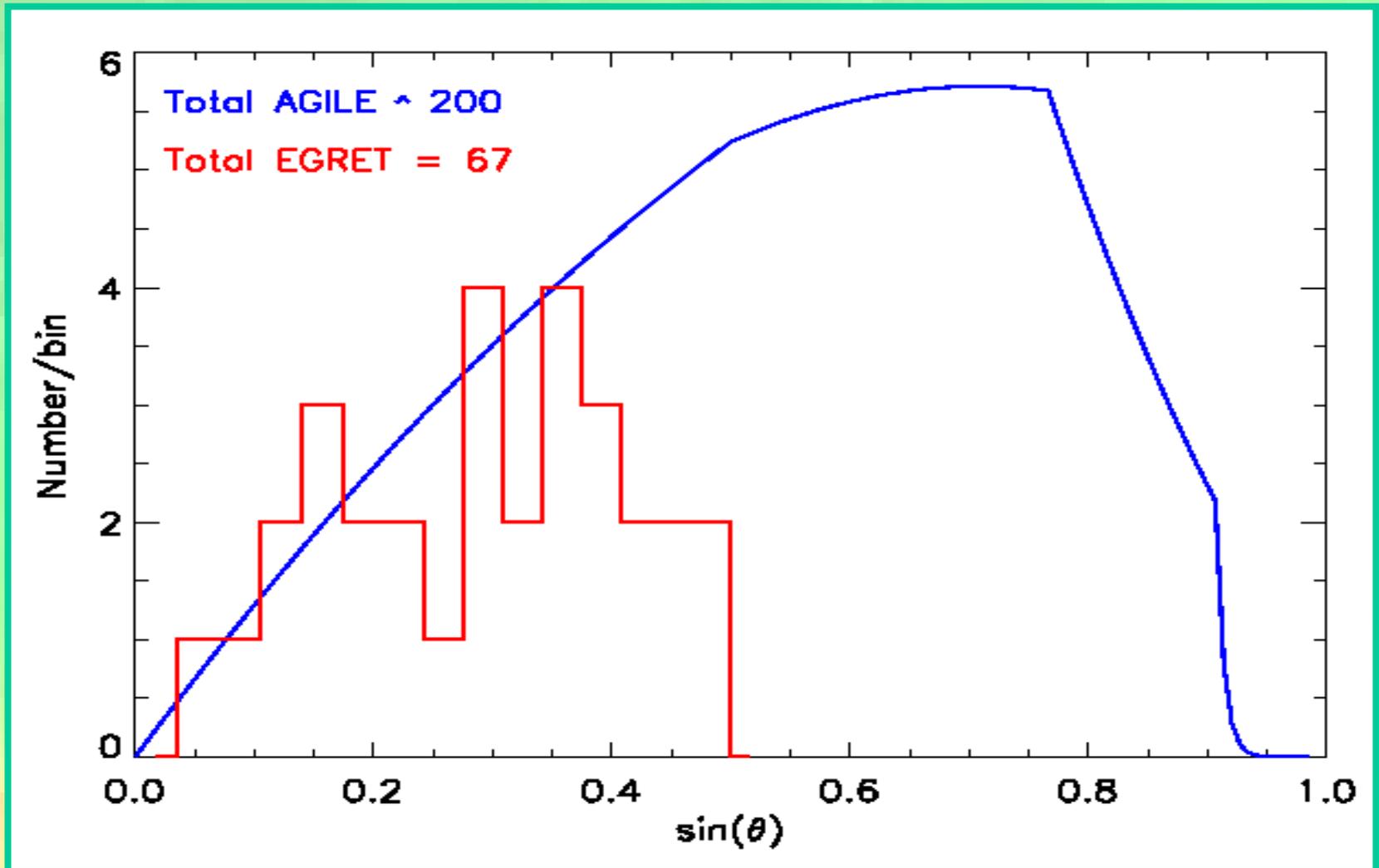


(4) Present Status

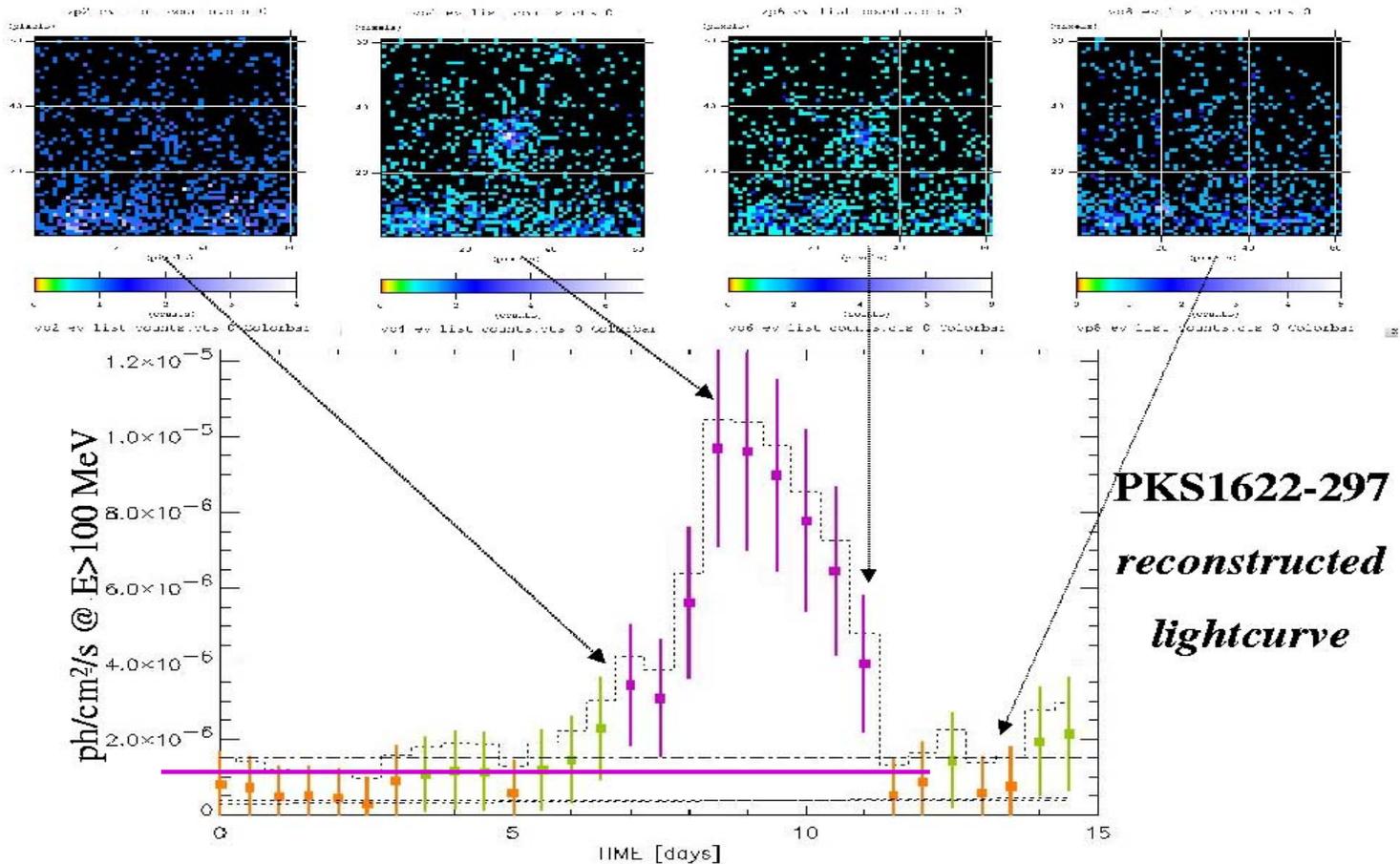
The γ -rays sky



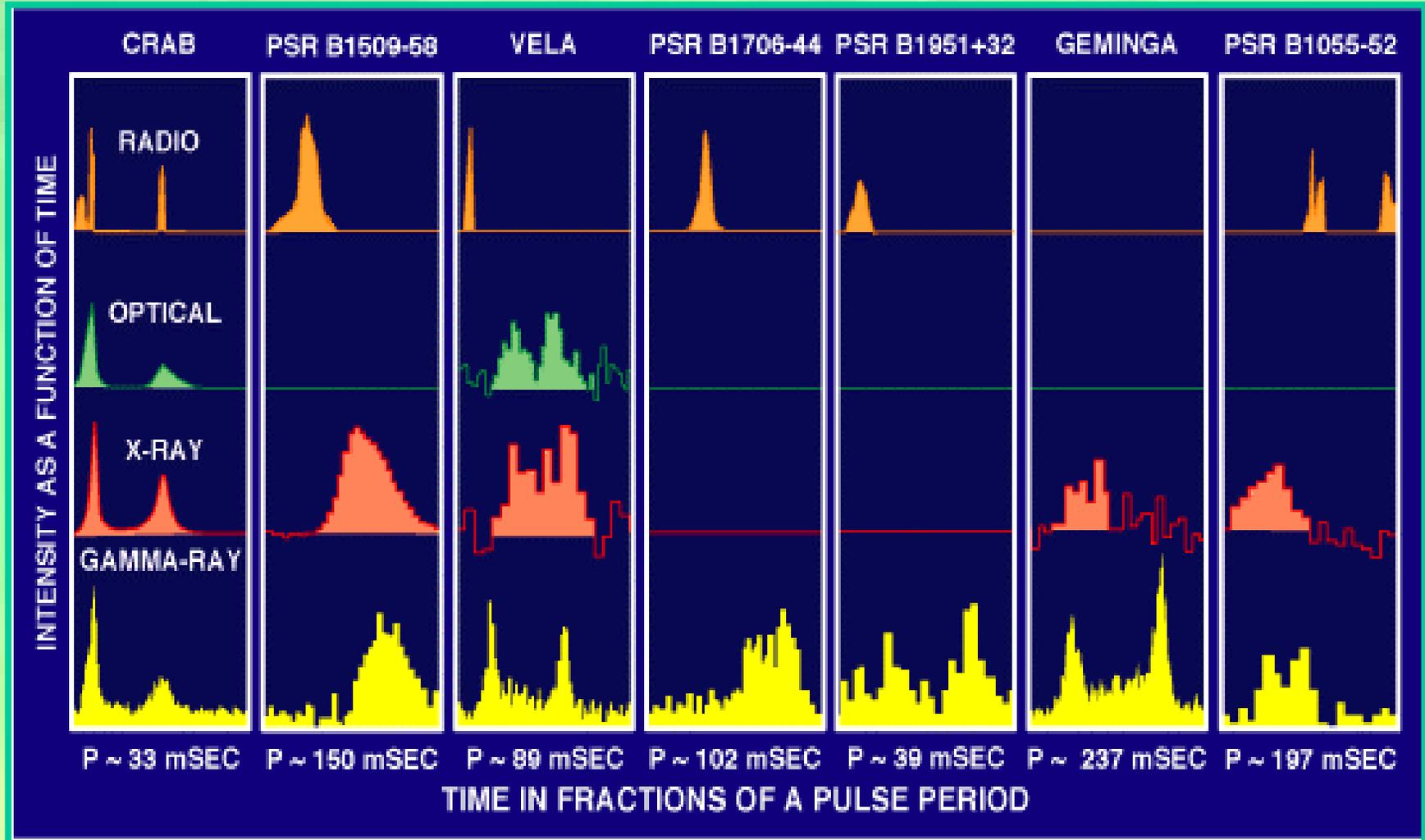
Blazars with AGILE



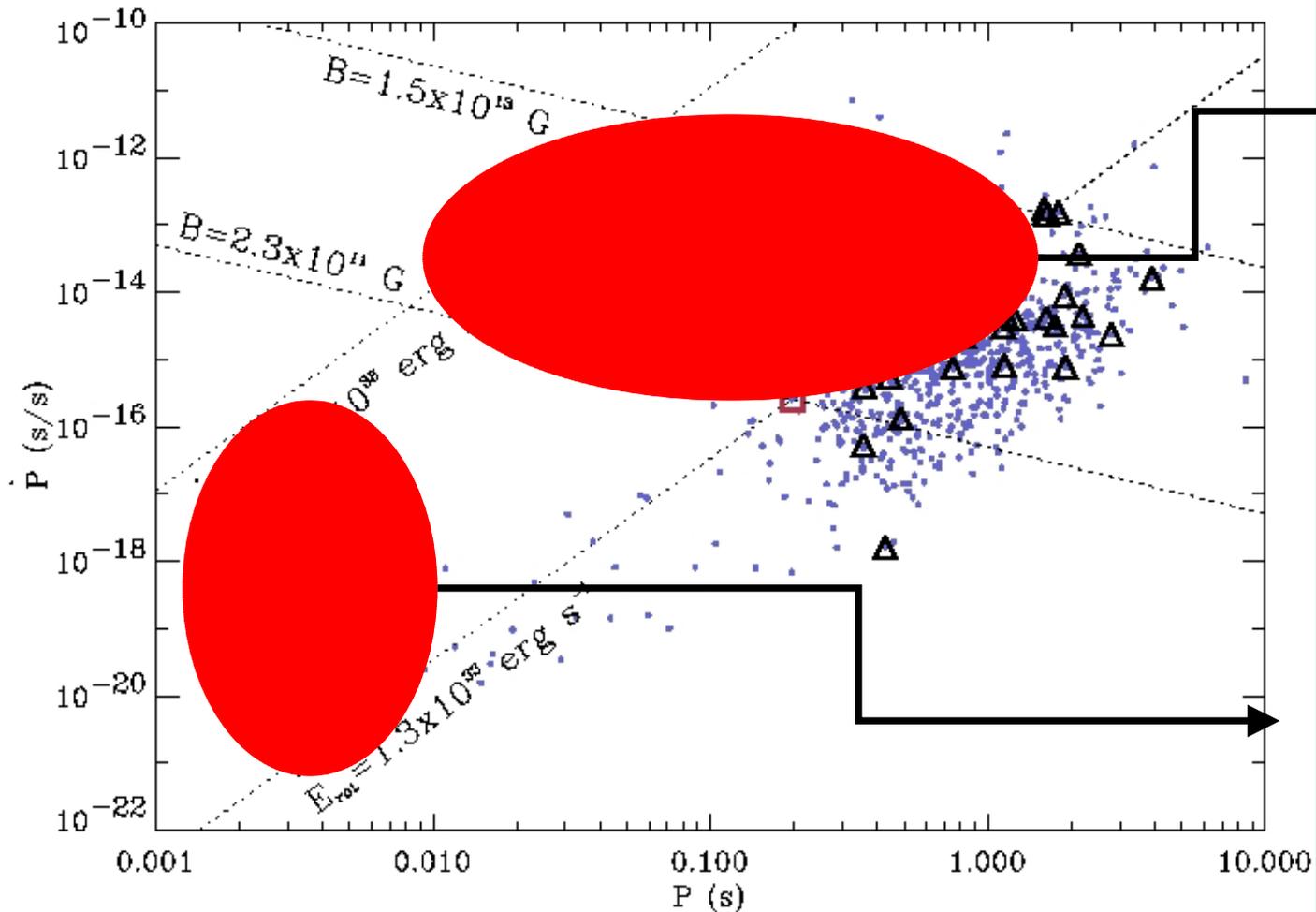
Blazars with AGILE



Pulsars with AGILE



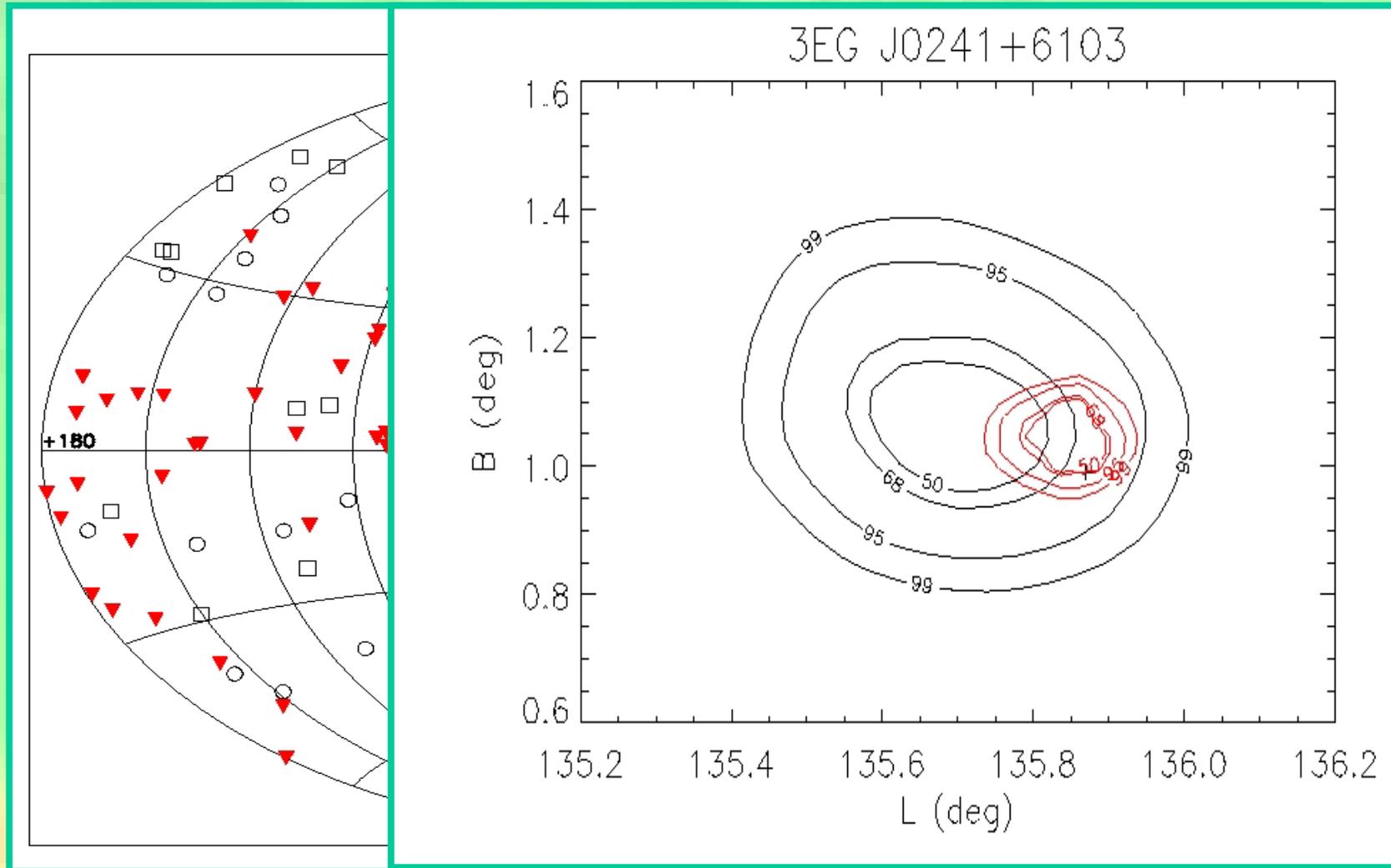
Pulsars with AGILE



Candidate γ PSR

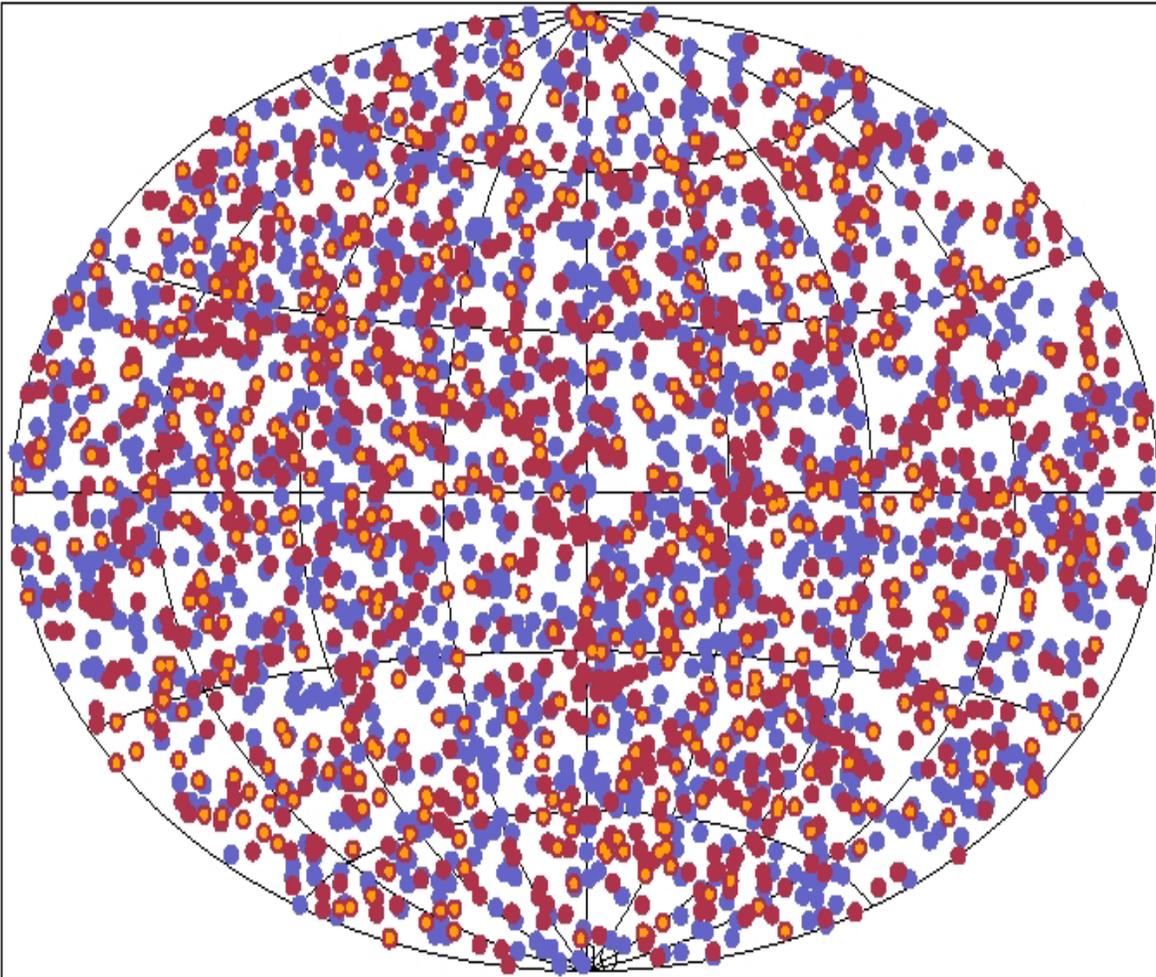
Millisec. γ PSR

Unidentified EGRET Sources



GRBs with AGILE

GRB position



SuperAGILE:

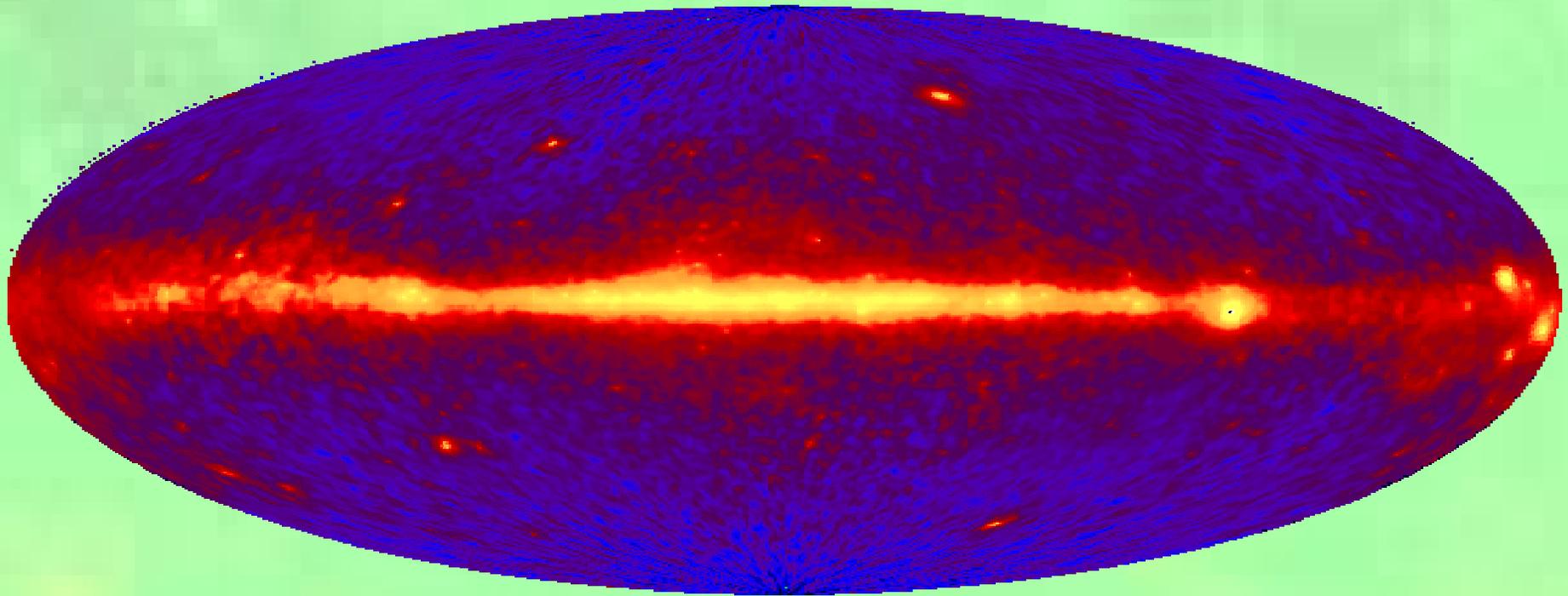
2/month

MiniCalorimetro:

10/month ($E < 1$ MeV)

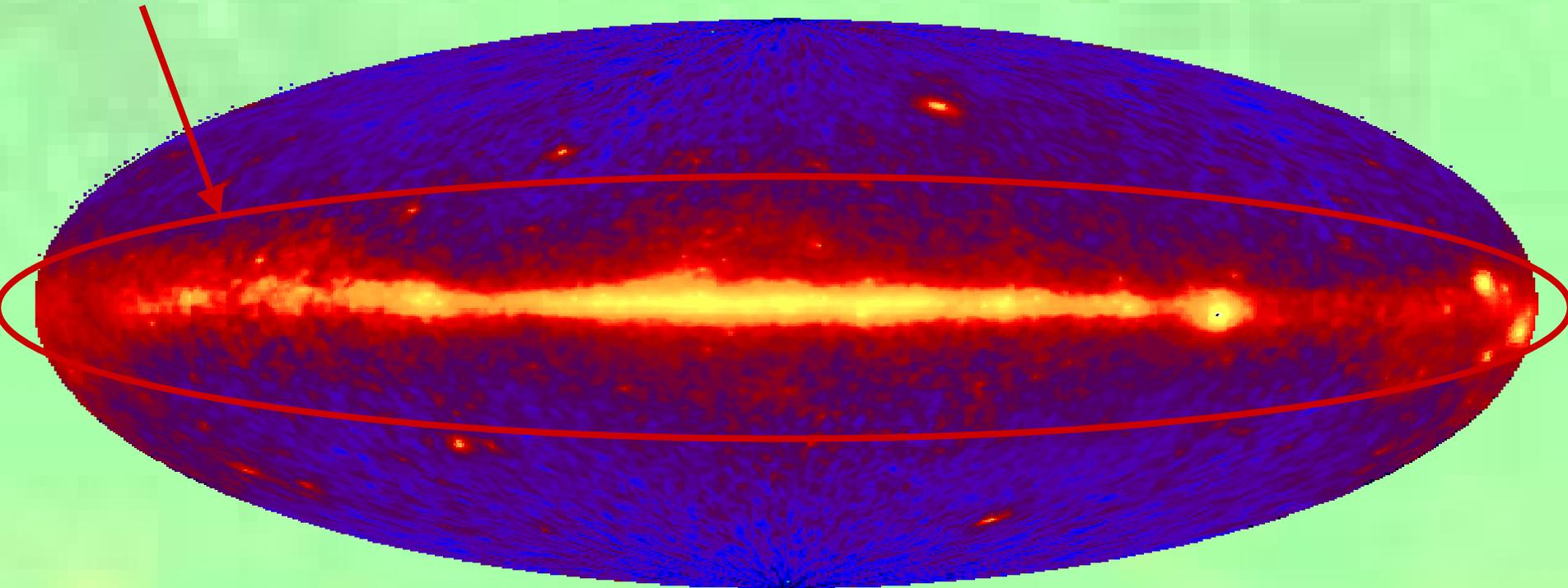
3/month ($E > 1$ MeV)

Why to study the γ -ray interstellar emission ?



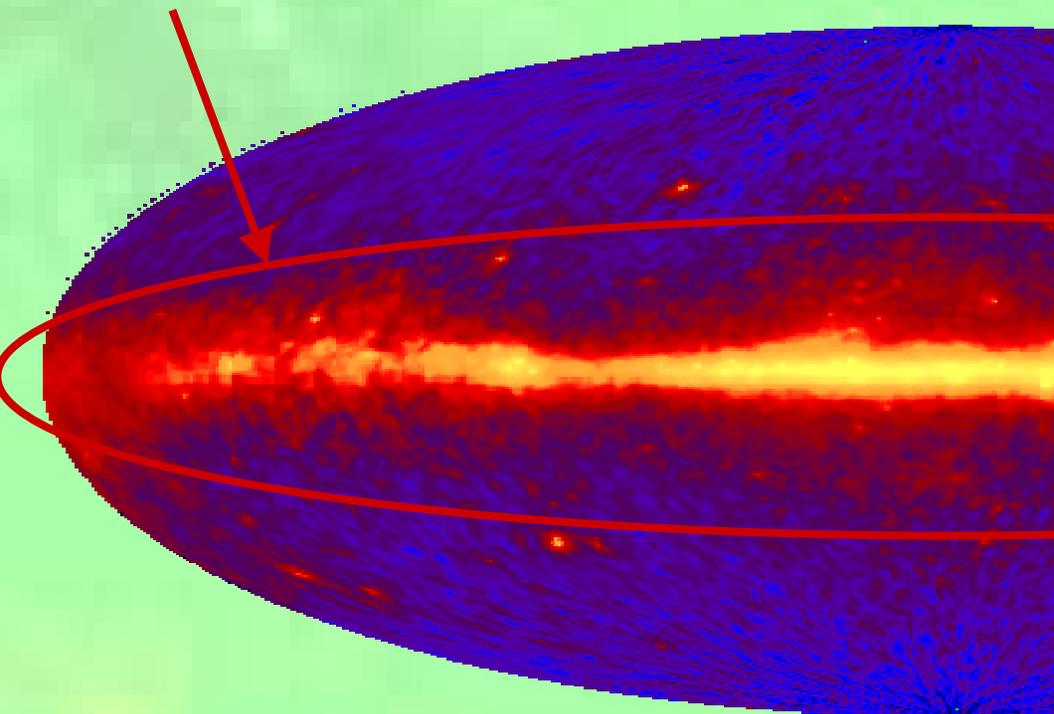
Why to study the γ -ray interstellar emission ?

As "signal": probe of
CR, IS Matter, ISRF



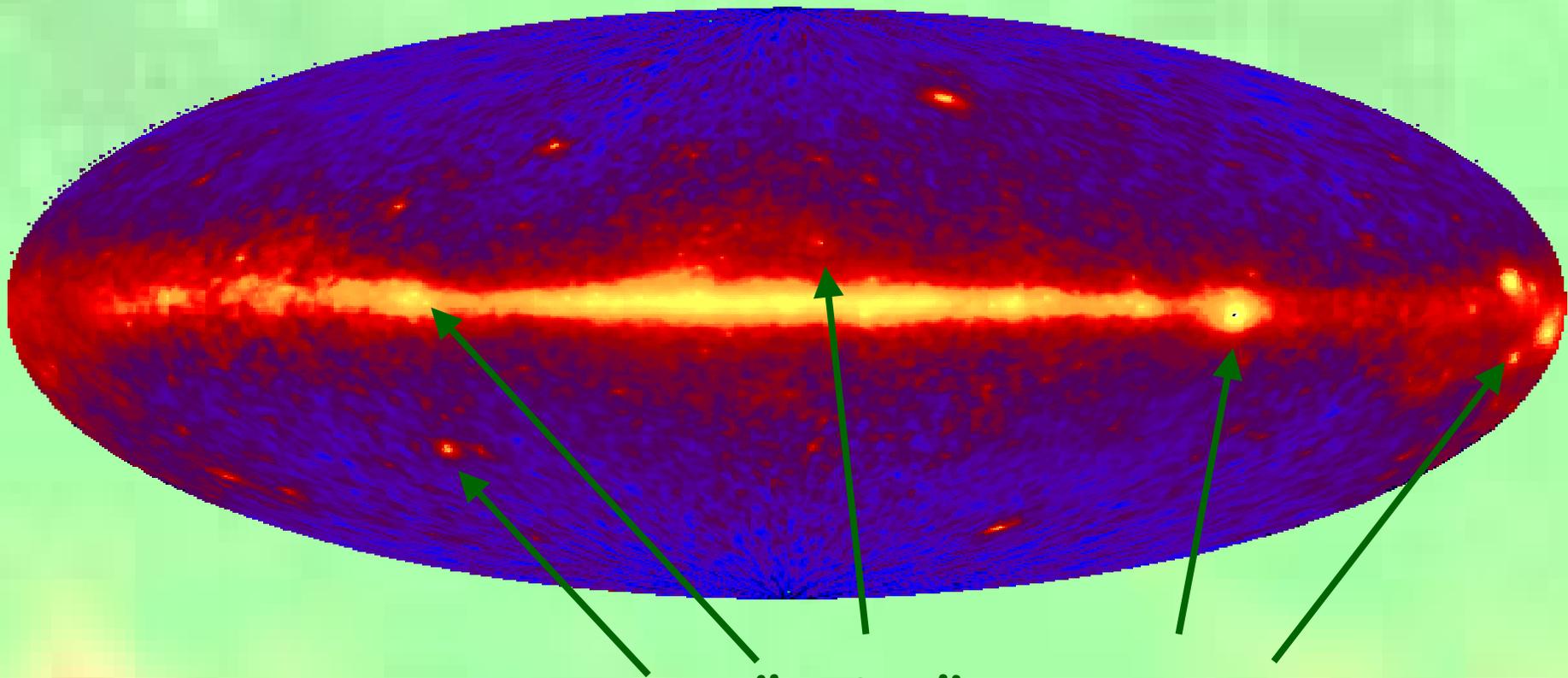
Why to study the γ -ray interstellar emission ?

As "signal": probe of
CR, IS Matter, ISRF



- **Origin of GeV excess (if confirmed !)**
 - Electronic harder spectrum ?
 - Protonic harder spectrum ?
- **Galactic vs local electronic spectrum**
- **Inhomogeneous gamma emissivity ?**
- **X ratio value and variation in Galaxy**
- **IC contribution to Diffuse emission**
- **Galactic vs Extragalactic diffuse emission**
- **CR sources**
 - SNR
 - Stellar associations ?

Why to study the γ -ray interstellar emission ?



As "noise": source identification and analysis.

Gamma-Ray Emission of Interstellar Medium Overview (1)

- Cosmic rays (p and e^-)
- Interstellar Matter
 - Neutral Hydrogen (60 %, 21 cm line)
 - Molecular Clouds (40 %, CO emission, X ratio)
- InterStellar Radiation Field (stars, dust, CBM)

Gamma-Ray Emission of Interstellar Medium Overview (2)

Emission processes:

- **Electron Bremsstrahlung:**
CR electrons + ISM nuclei \rightarrow γ rays
- **Neutral π decay :**
CR protons + ISM nuclei \rightarrow $\pi^0 \rightarrow \gamma$ rays
- **Inverse Compton :**
CR electrons + ISRF photons $\rightarrow \gamma$ rays

No gamma-ray absorption

Gamma-Ray Emission of Interstellar Medium Overview (3)

<i>Gamma-ray emissivity</i>	Cosmic electrons	Cosmic Protons
HI regions	$\sigma_{br} F_e n_{HI}$	$\sigma_{pp} F_p n_{HI}$
Molecular Clouds	$\sigma_{br} F_e n_{CO} X_{ratio}$	$\sigma_{pp} F_p n_{CO} X_{ratio}$
ISRF (+CRB)	$\sigma_{IC} F_e U_{ph}$	--

Proton-proton collisions

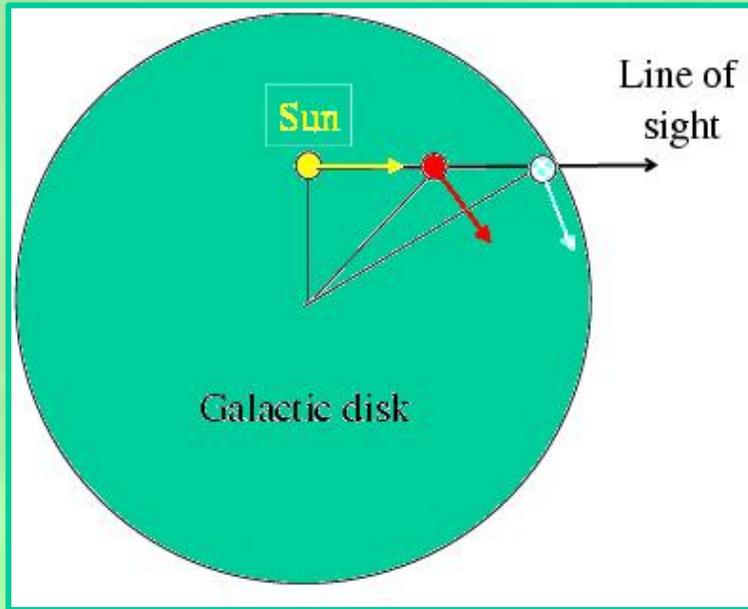
Bremsstrahlung

Inverse Compton

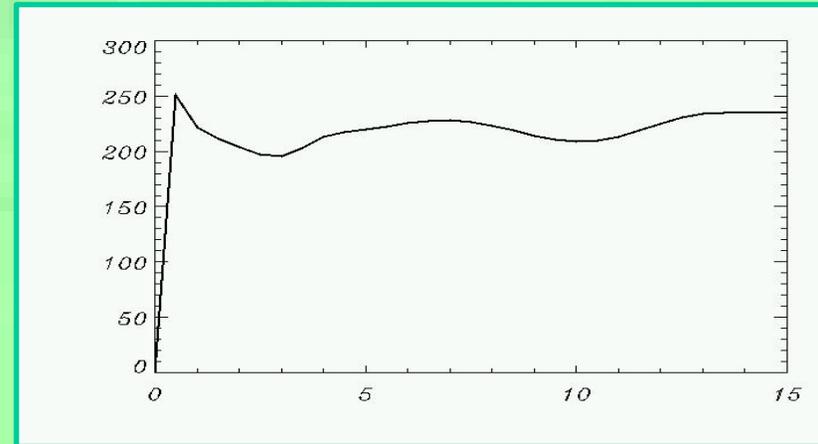
The unknowns are :

F_e , F_p , X_{ratio} , U_{ph}

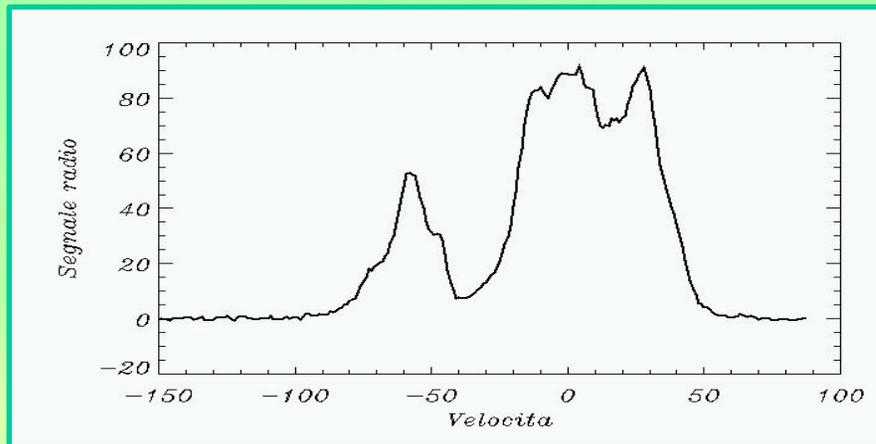
Radio Data deprojection



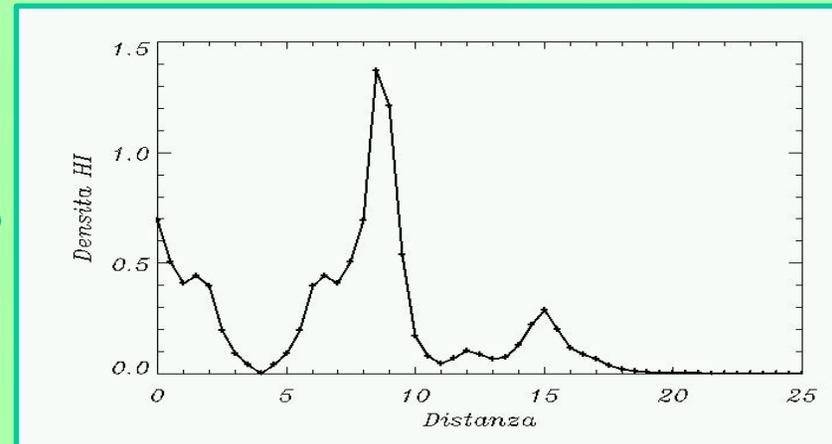
Galactic rotation curve
Clemens 1985



Radio Data



Gas density



Neutral Hydrogen Survey



Leiden-Dwingeloo survey
at 21 cm

(Hartmann et al 1997)

Spatial resolution: 30'

Velocity resolution: 1.03 km/s

Velocity range: -450,400 km/s

Sensitivity: 0.07° K

CO Survey

(Dame et al. 2001)



CO observation

J 1→0 115 GHz

31 survey combined

Spatial resolution: 12' or more

Velocity resolution: 0.65 km/s

Sensitivity: 0.62° K

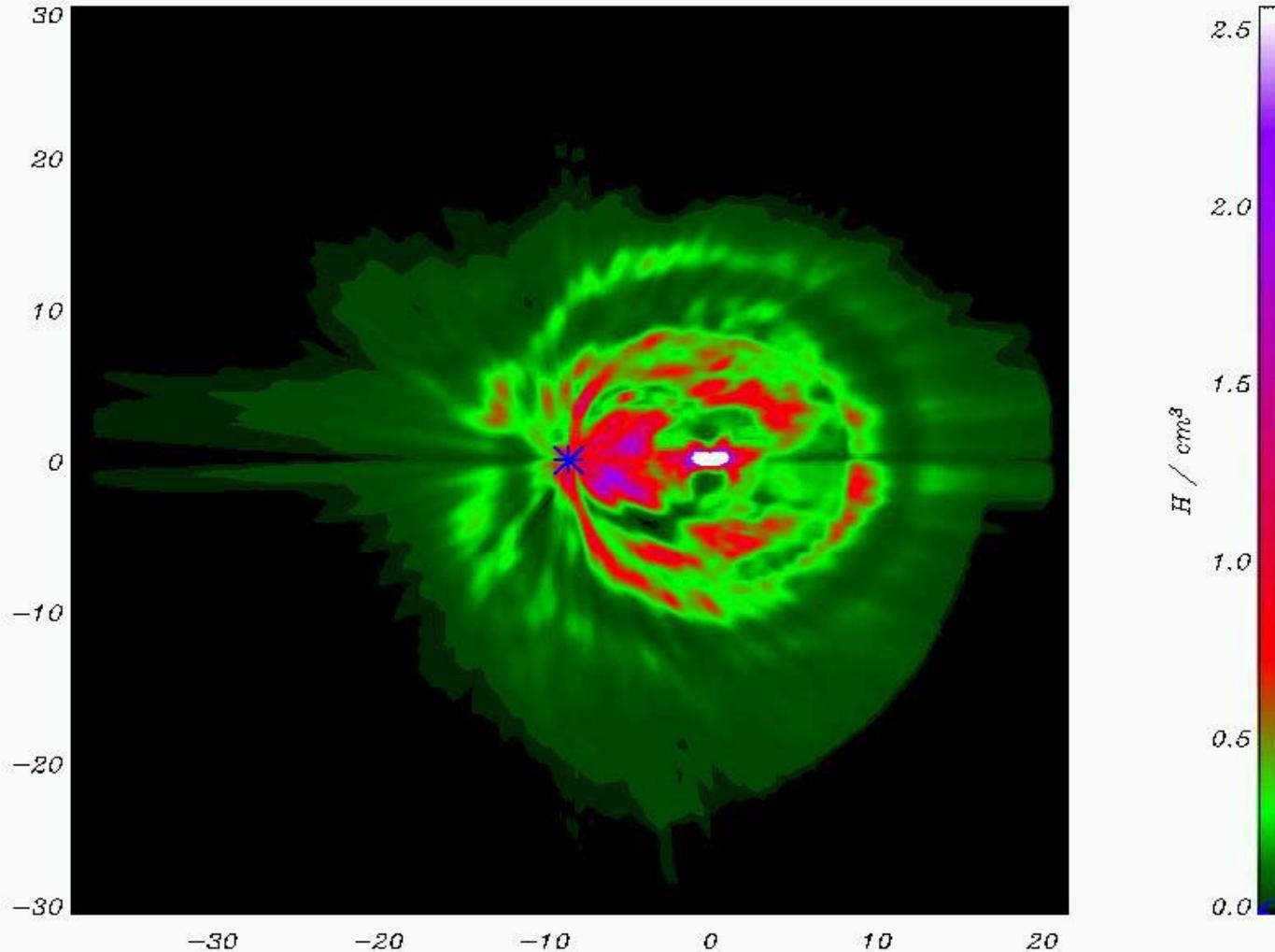
$$X = n_{\text{HI}}/n_{\text{CO}} = 1.8 \cdot 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ km}^{-1} \text{ s}$$

CO Survey \rightarrow Molecular Clouds



Hydrogen distribution

H mean density (averaged on $|b| < 5$)

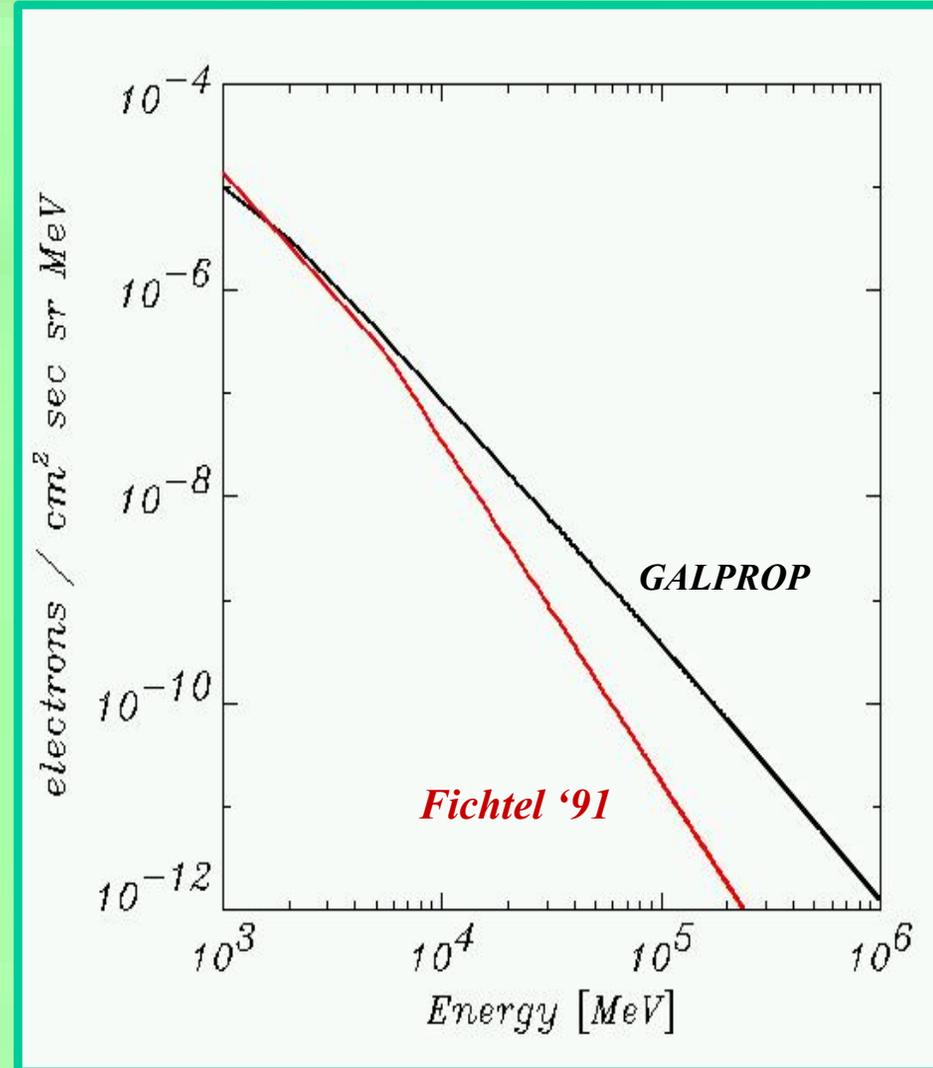


Interstellar Radiation Field

- Cosmic Background Radiation
- **Model** of the Interstellar Radiation Field
 - Far Infrared
 - Near Infrared
 - Optical/UV

Cosmic-Rays

- Trying with different cosmic ray models
- Physical models
 - ✂ Sources, diffusion and energy loss simulated
 - ✂ GALPROP (Strong & Moskalenko)



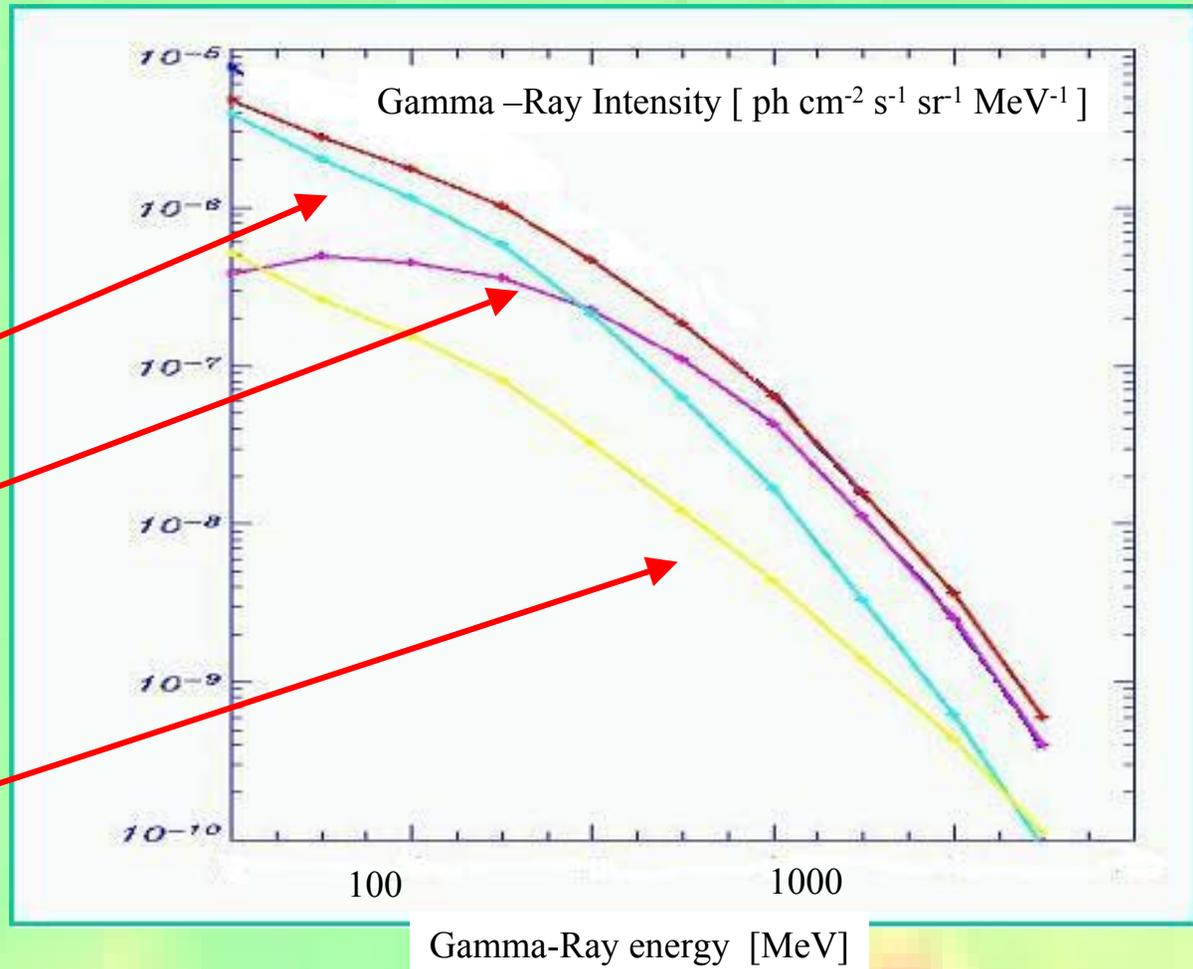
Gamma-Ray Spectrum

$$S(E) = \frac{1}{4\pi} \int \left[q_{pp}(r, E)n(r) + q_{br}(r, E)n(r) + q_{IC}(r, E)U(r) \right] dr d\Omega$$

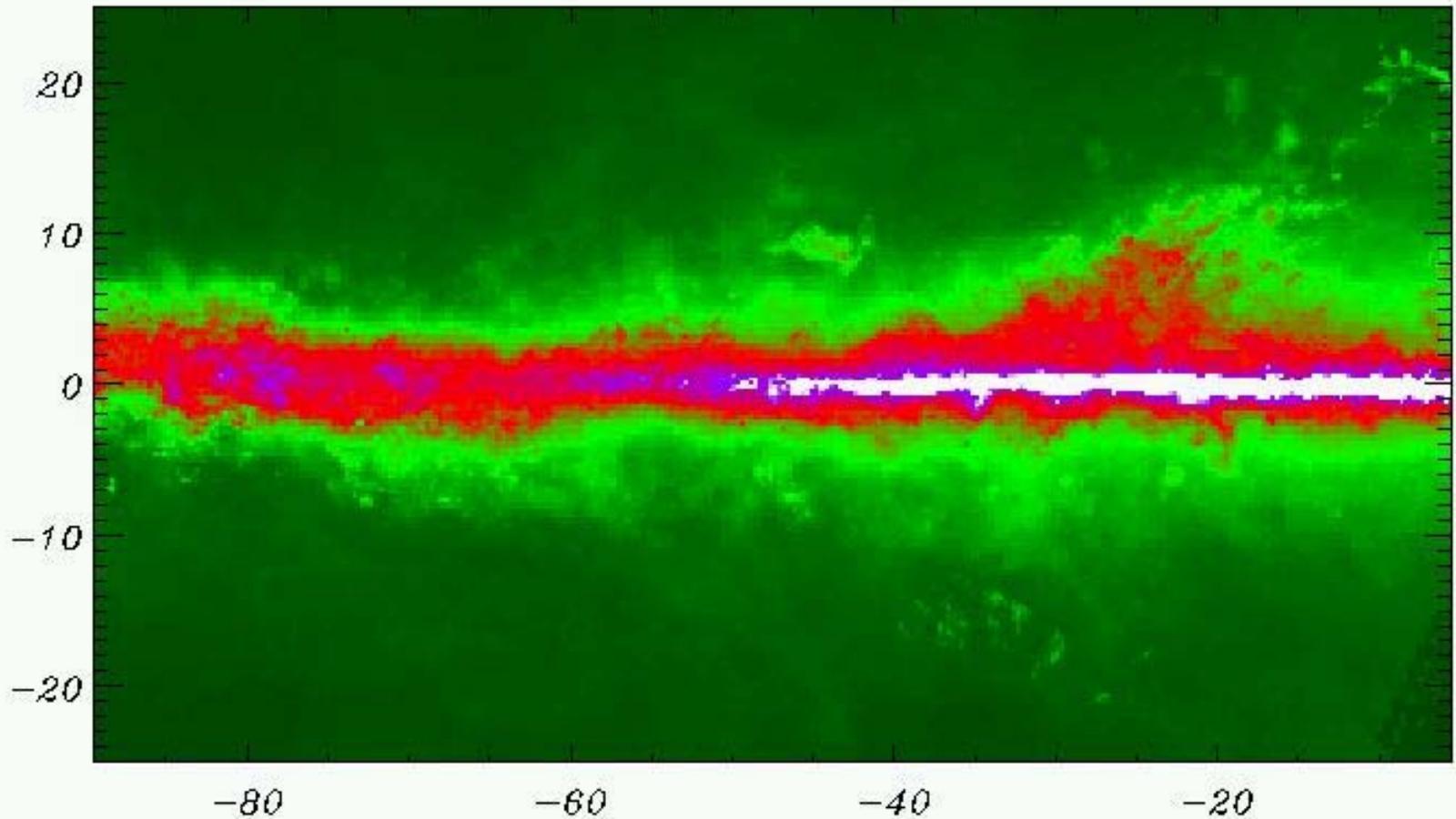
Electron
Bremsstrahlung

π^0 decay

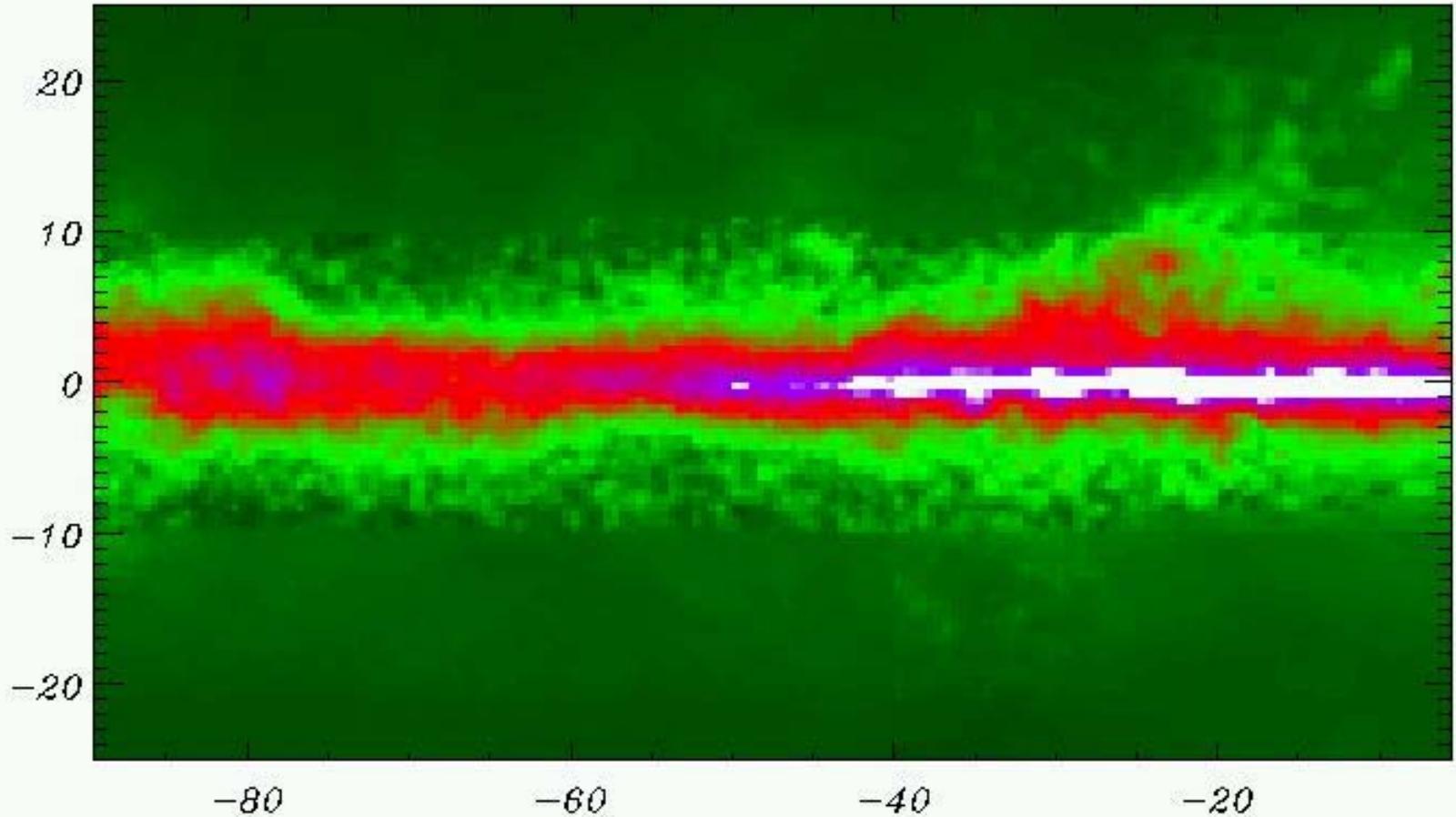
Inverse Compton



The **AGILE** γ -ray emission model (I quadrant)

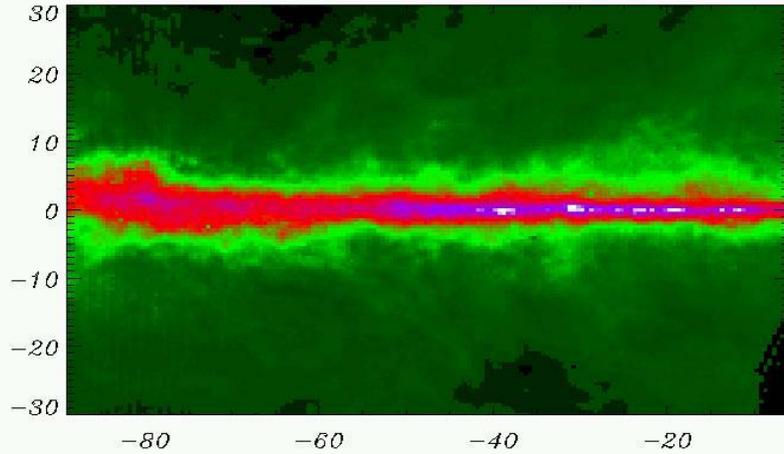


The EGRET γ -ray emission model (I quadrant)

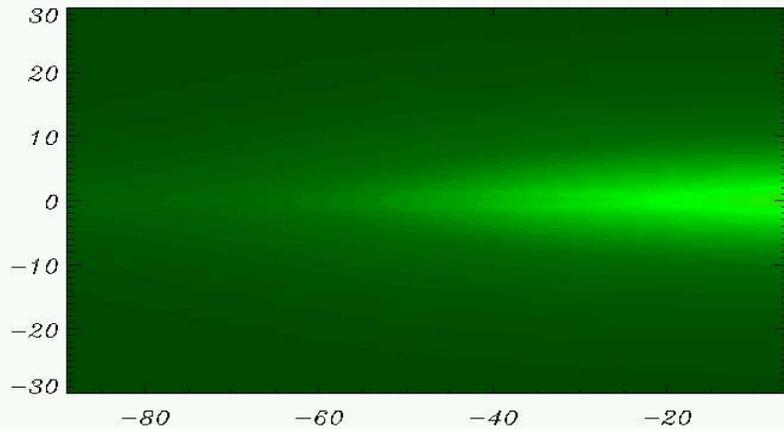
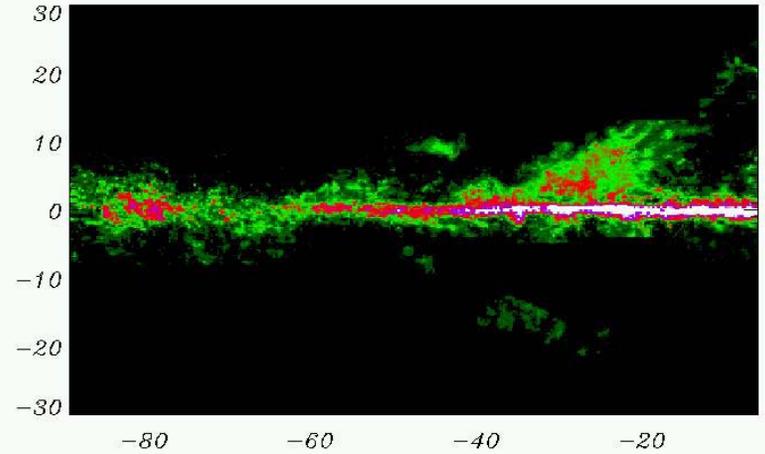


The **AGILE** γ -ray emission model (I quadrant)

HI

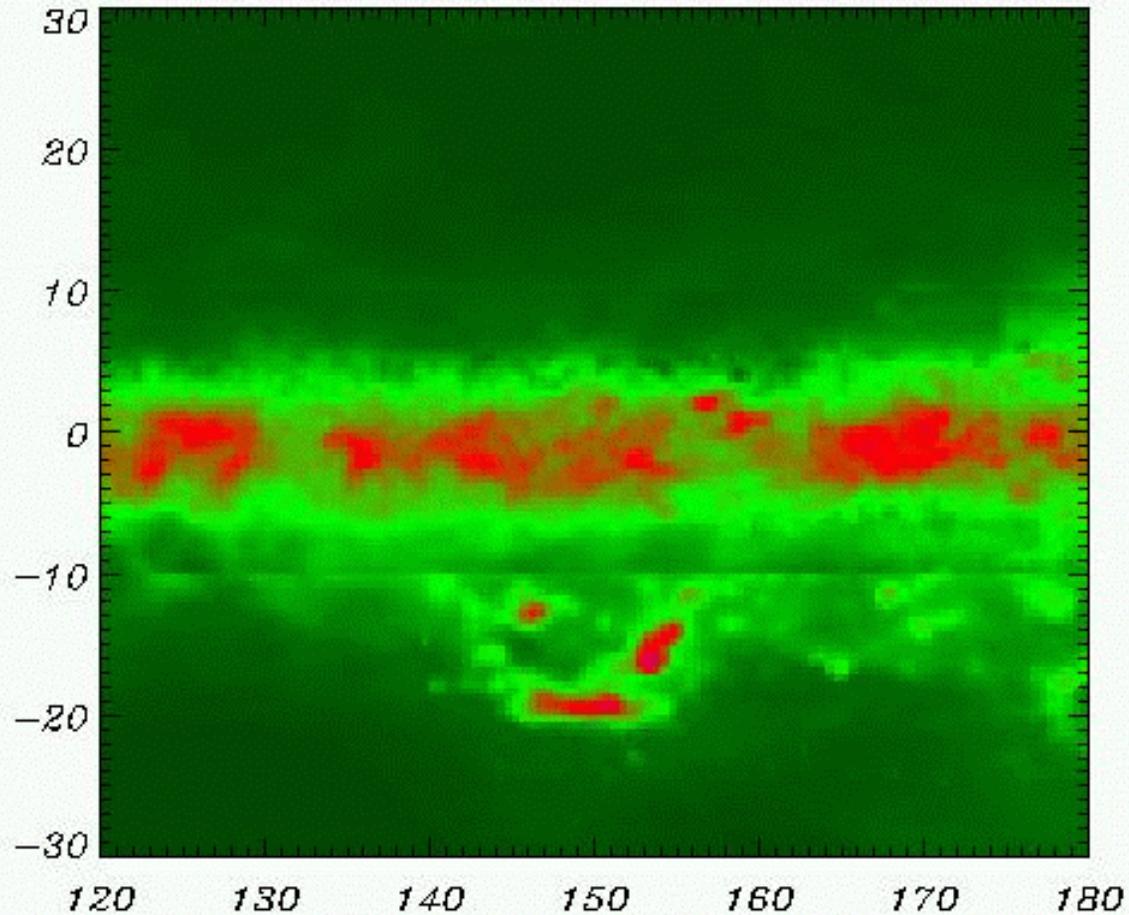


H₂

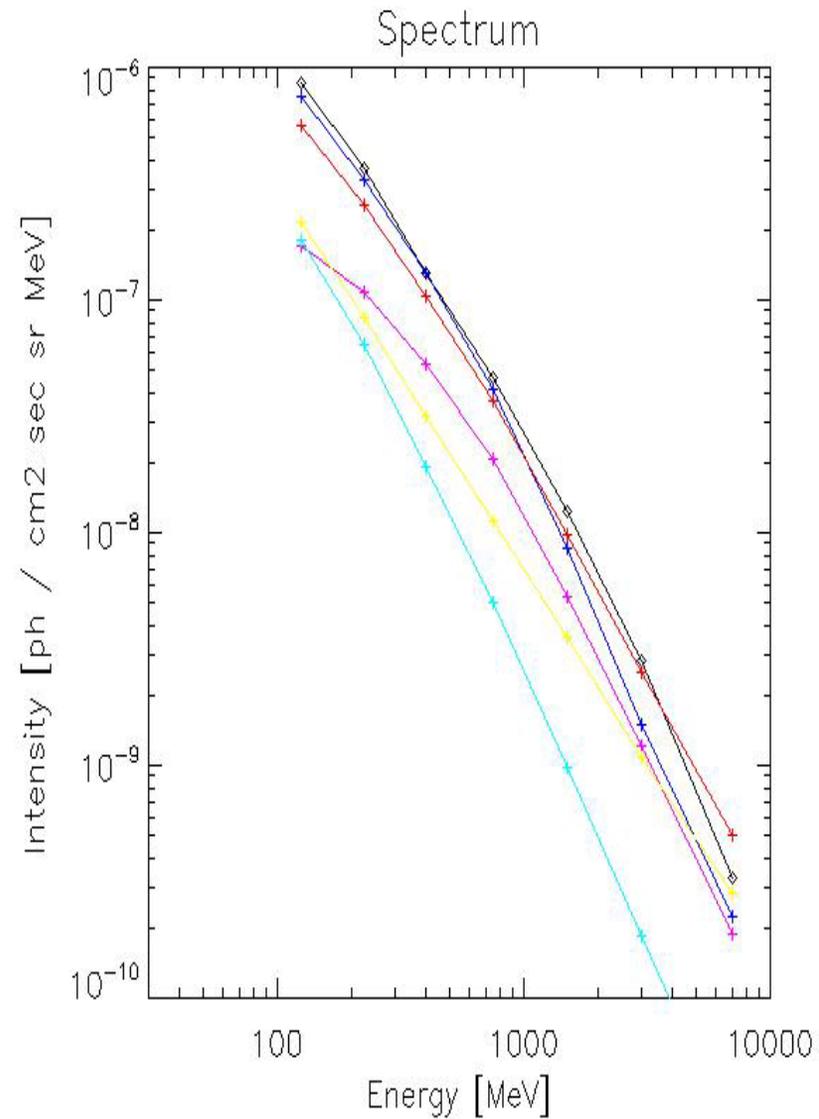
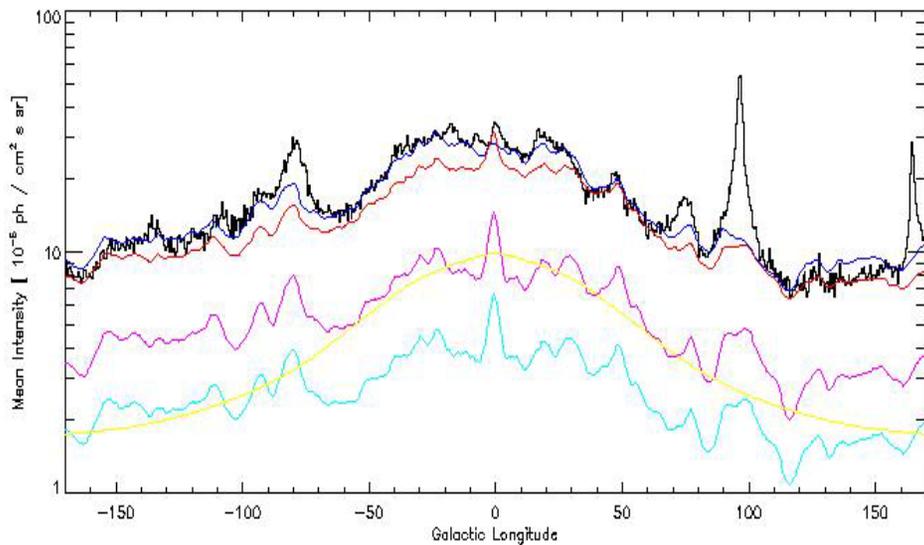
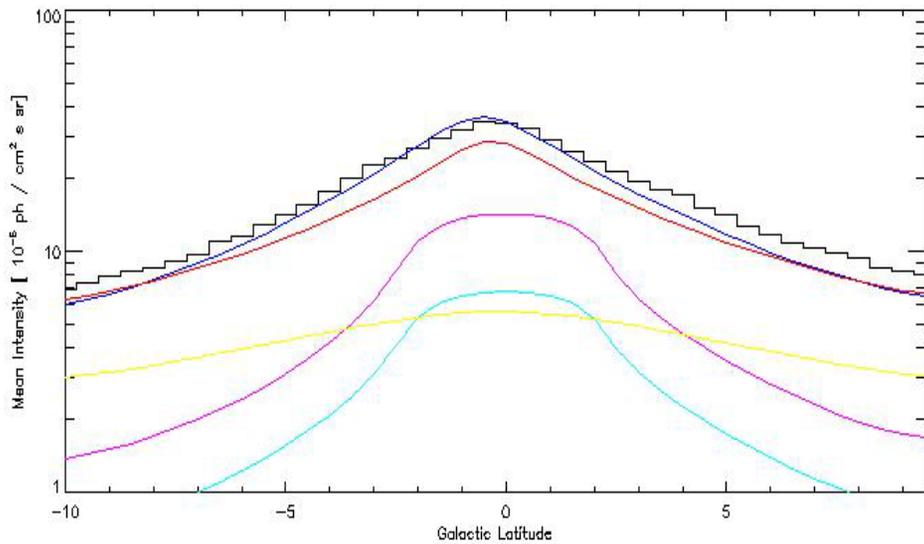


ISRF

The **AGILE** γ -ray emission model



The **AGILE** γ -ray emission model



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(1) Hardware

- GRID
- SuperAGILE
- AntiCoincidence

(2) Scientific Software

- Hits to photons
- Photons to sources

(3) Science

- AGN
- Pulsars
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- UnID Sources
- Diffuse Galactic Emission

(4) Present Status

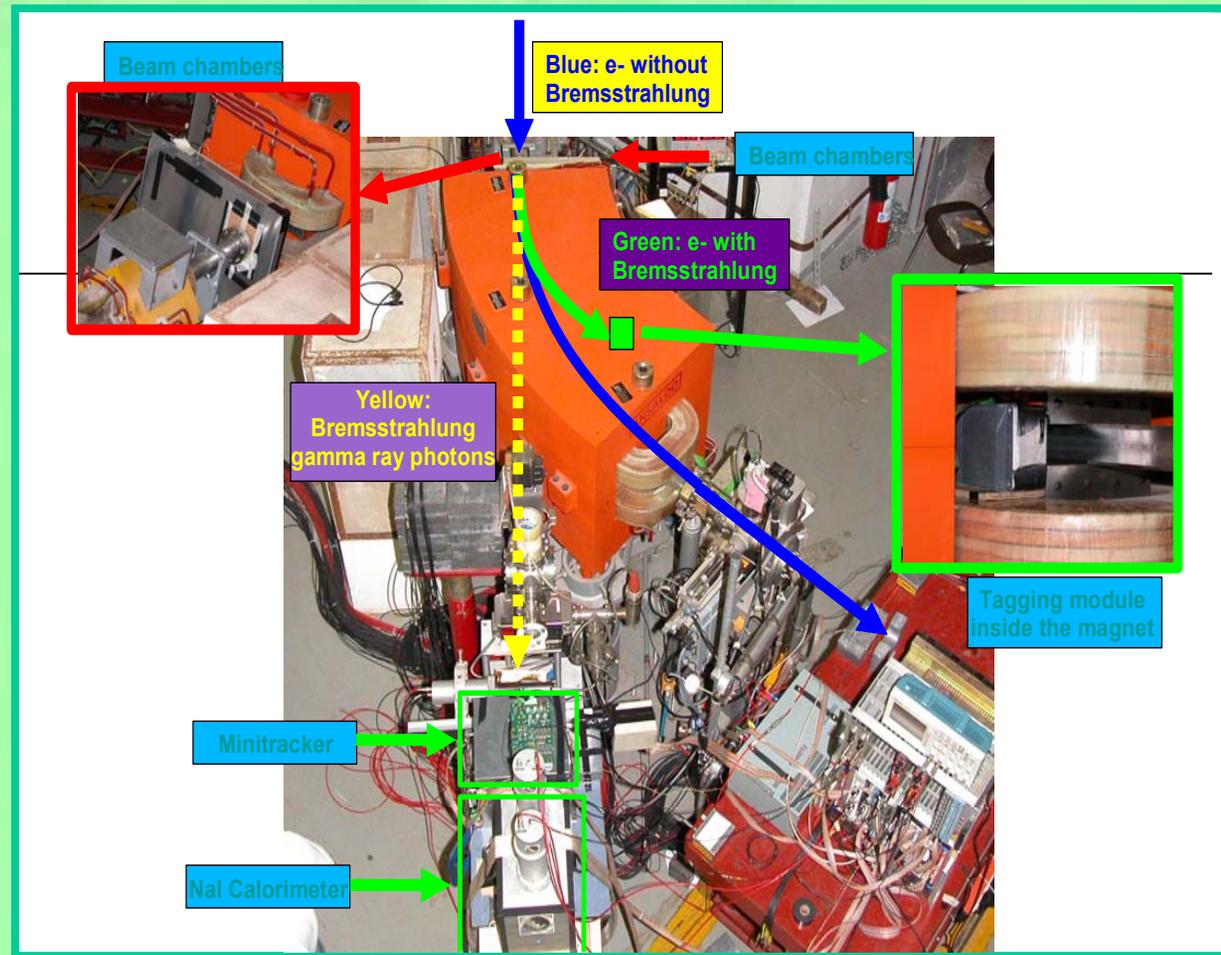


AGILE Scientific Calibration

AGILE
 γ -ray
calibration

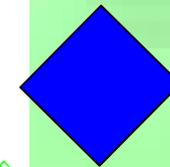
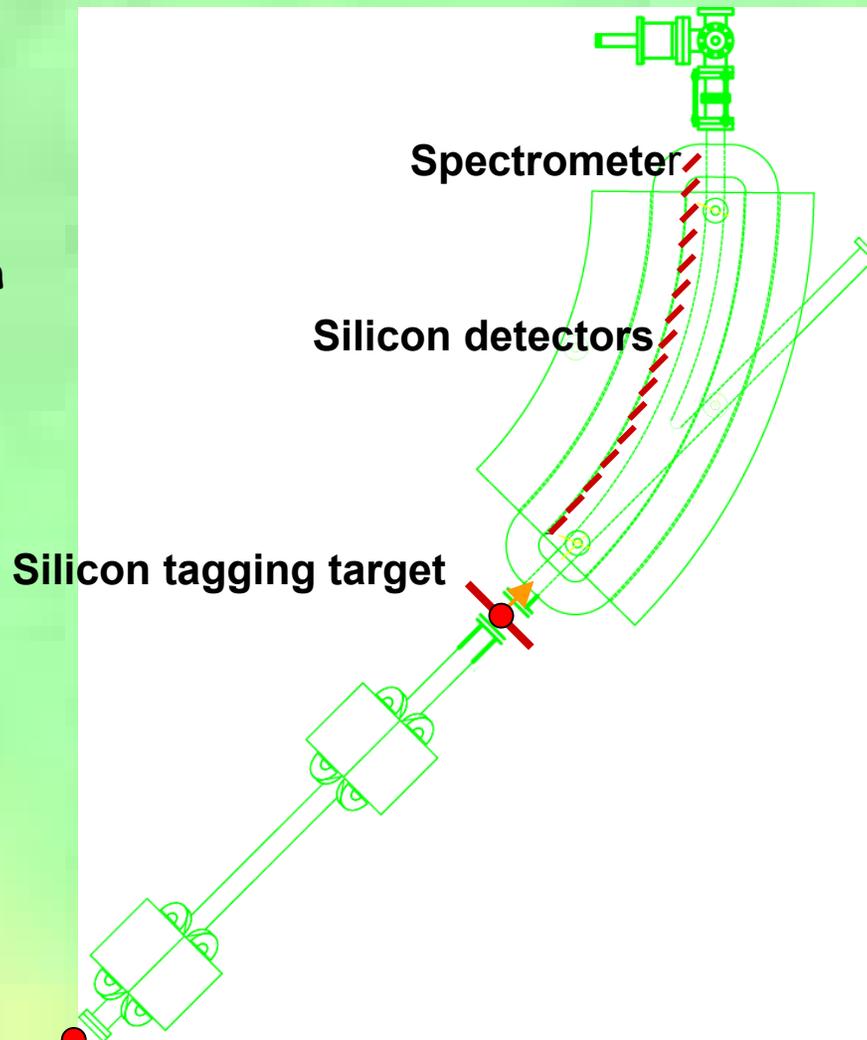
Laboratori
Nazionali
Frascati

(November 2005)
– BTF facility



INFN-LNF-BTF Photon-Tagged Source AGILE GRID Photon Calibration

The AGILE Gamma Ray Imaging Detector calibration at BTF is aimed at obtaining data for all relevant geometries and background conditions. BTF can provide data in the energy range (30-700 MeV)

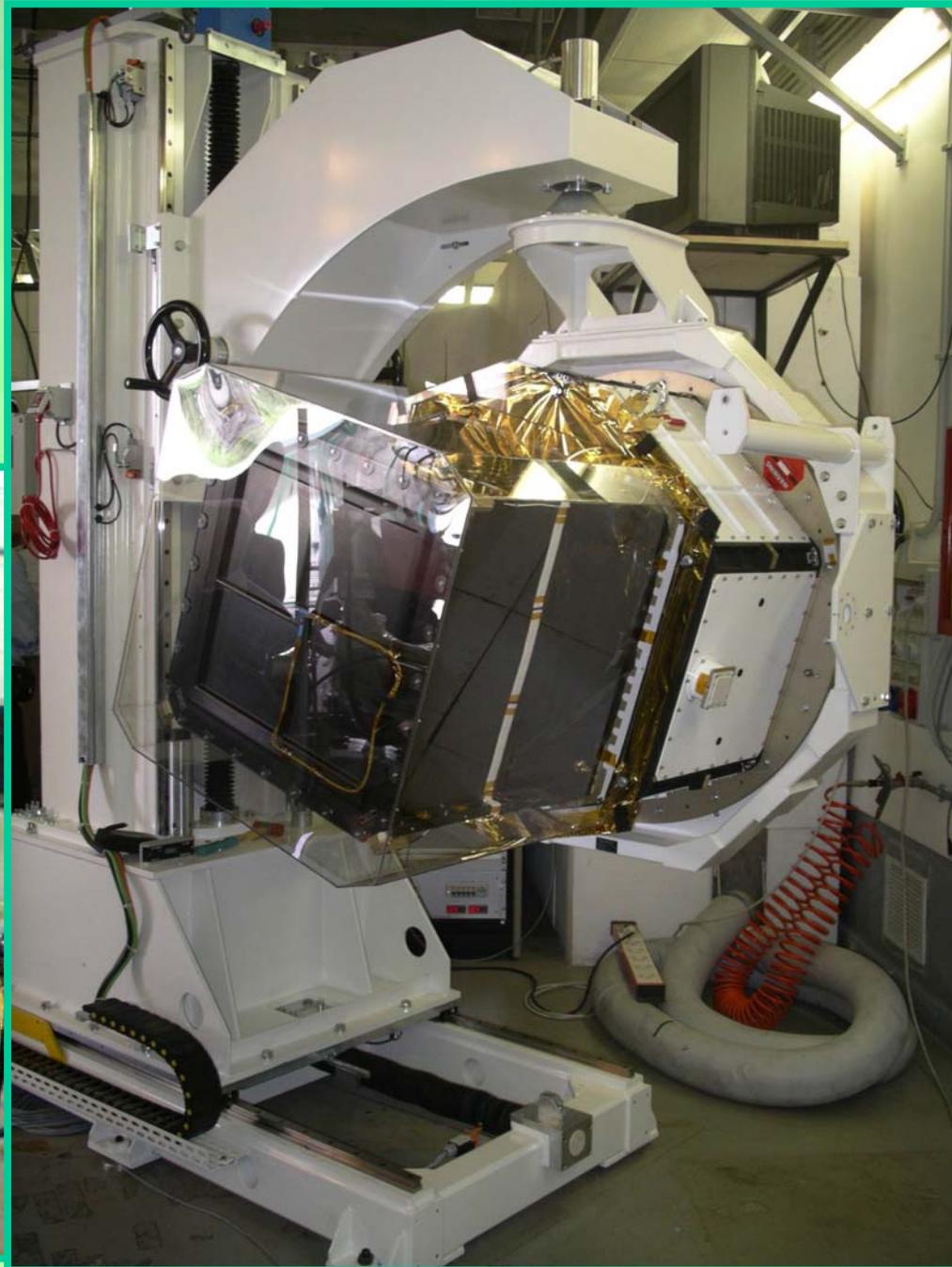


**AGILE
Payload**

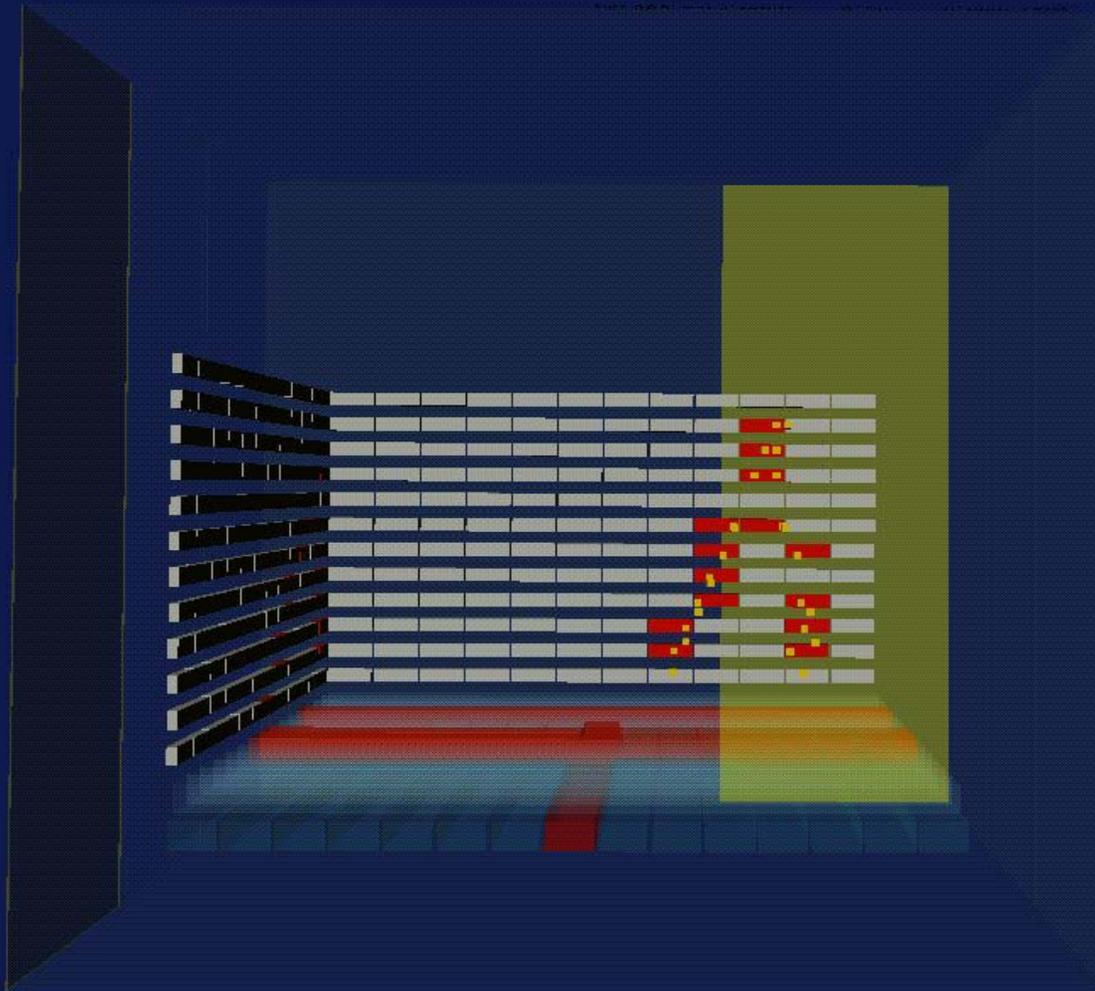
BTF-AGILE Schedule

- photon tagging system (PTS)
- spectrometer PTS calibration
- final equipment test (Oct.)
- AGILE calibration, 2-3 weeks of data collection

Beam Test Facility



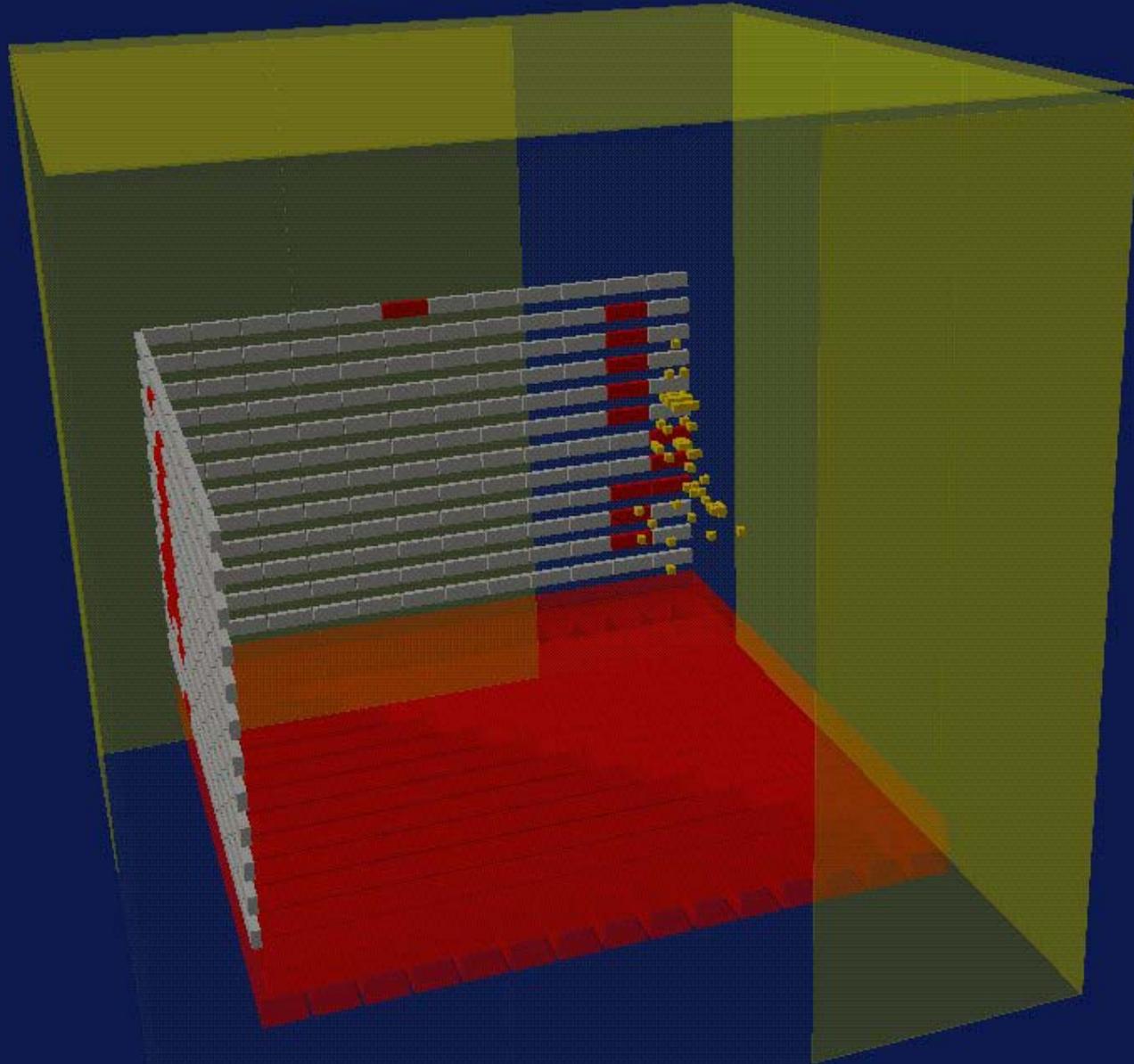
AGILE first photon at LNF



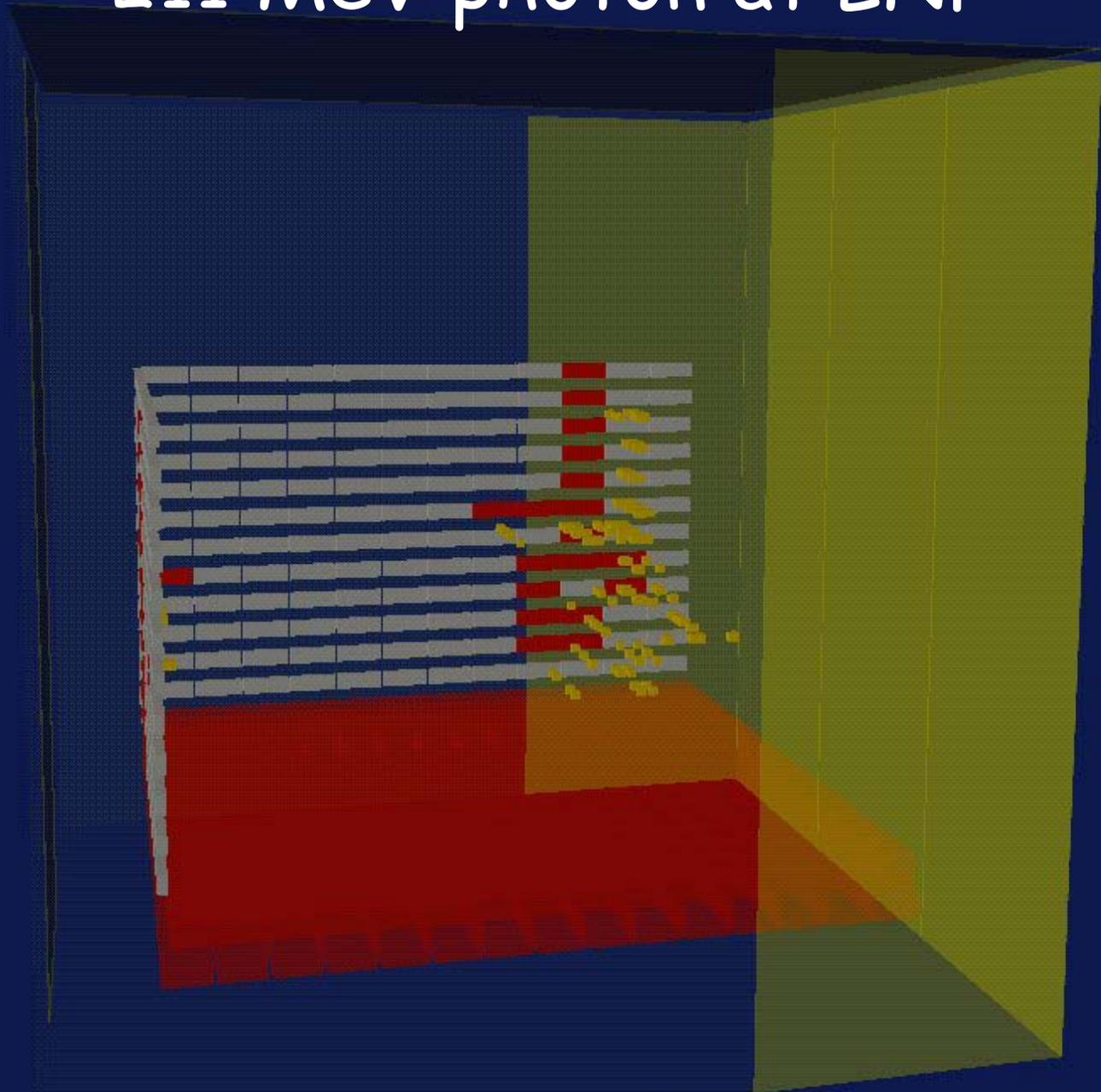
37 MeV photon at LNF



124 MeV photon at LNF

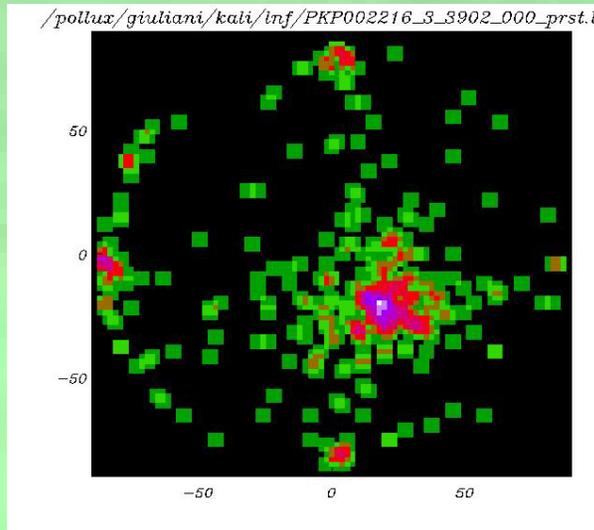


211 MeV photon at LNF

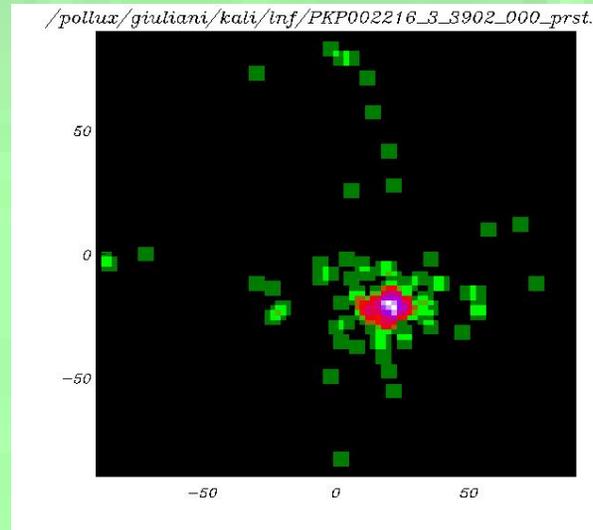


AGILE first source !

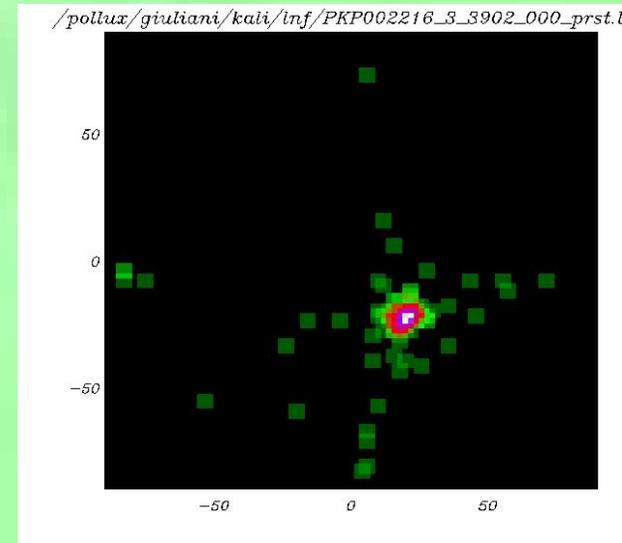
10-50 MeV



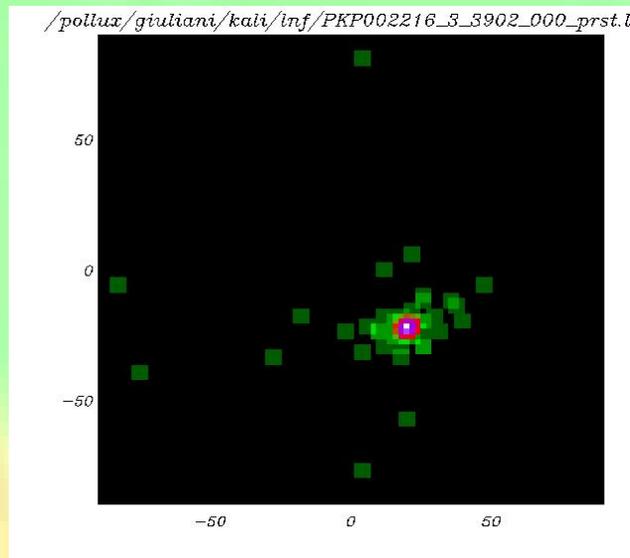
50-100 MeV



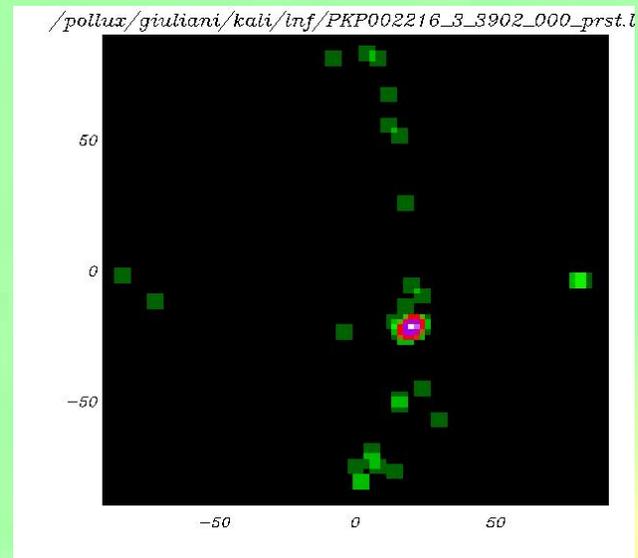
100-200 MeV



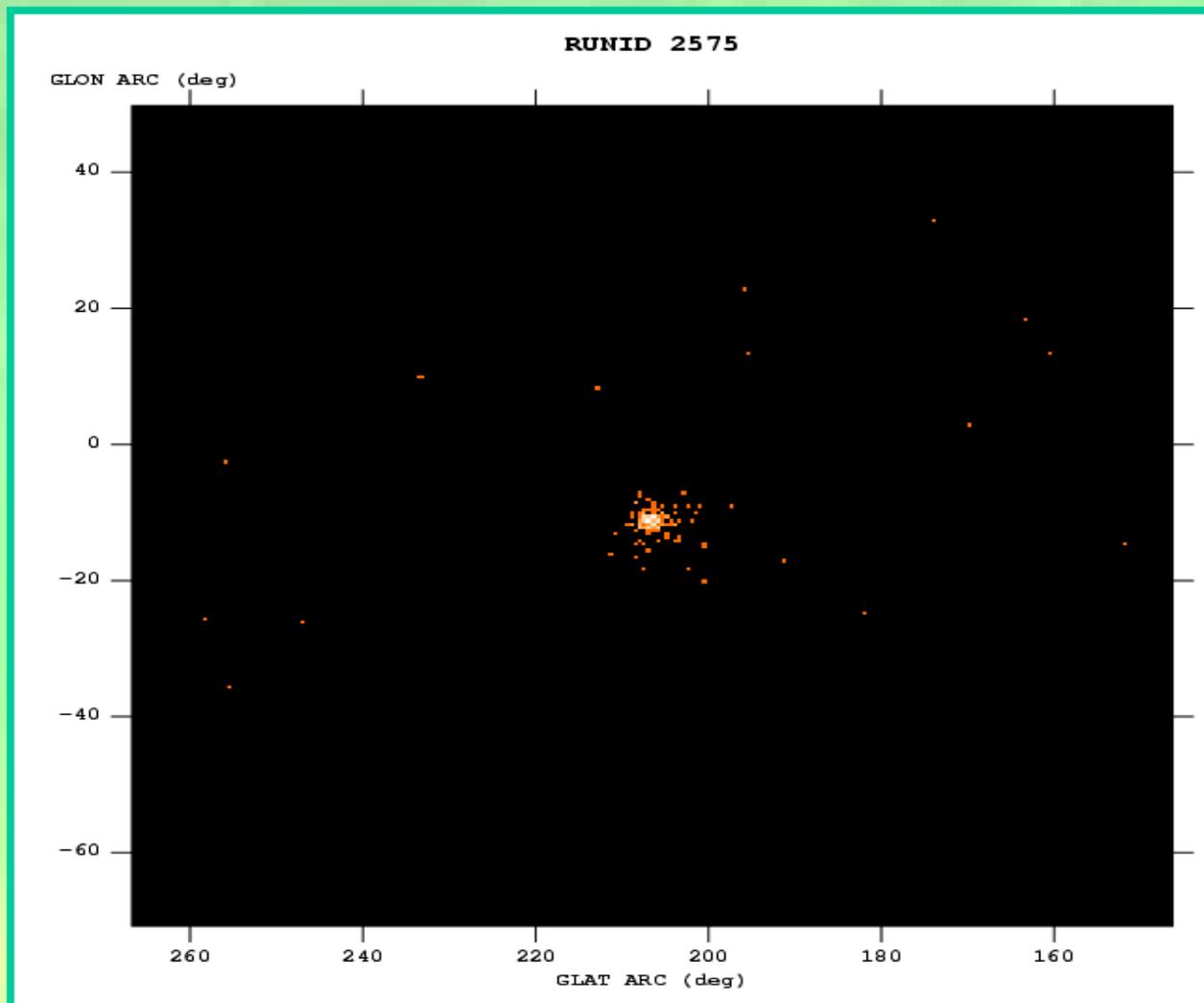
200-400 MeV



400-500 MeV



AGILE first source !



**AGILE-GRID
source
reconstructed
by the Kalman
Filter and
background
subtracted**

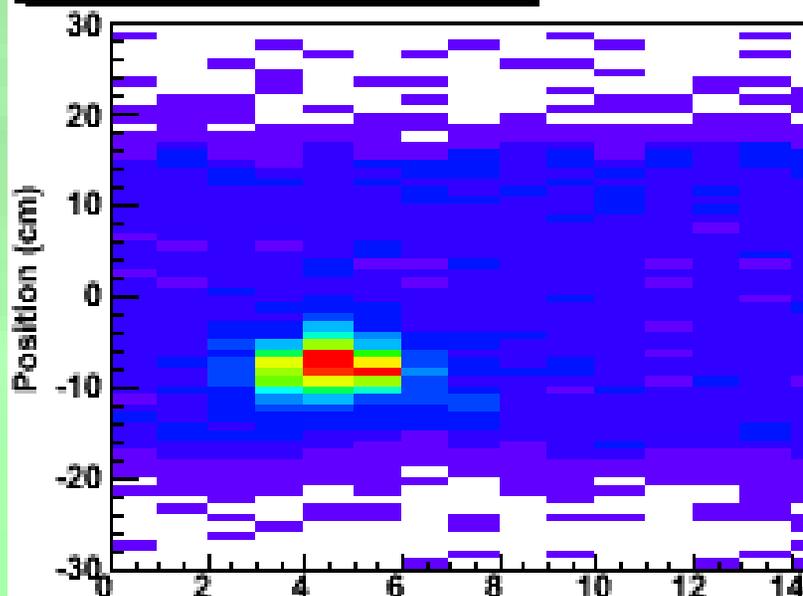
**(in LNF-BTF,
Nov. 2005)**

AGILE MCAL "imaging" of an MeV gamma-ray beam (Brems photons at LNF-BTF, AGILE calibr. run n. 2245)

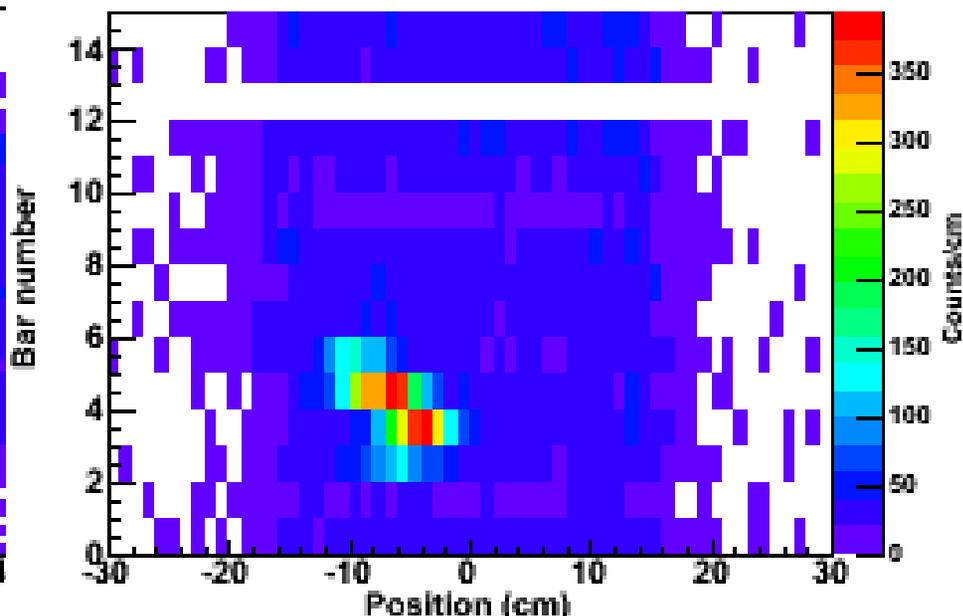
$E_{\text{beam}} = 450 \text{ MeV}$ beam hit coordinates (13, 523.01), $\theta = 30^\circ$ $\varphi = 135^\circ$ MCAL Burst mode (30.09)

300 > TIME < 600 sec, Beam ON, EVENTS WITH $E > 2 \text{ MeV}$

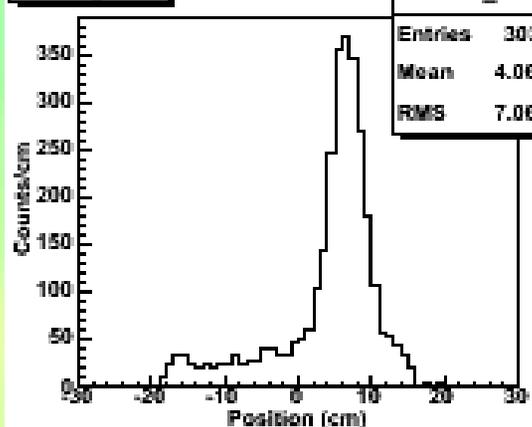
Events distribution on X plane



Events distribution on Z plane



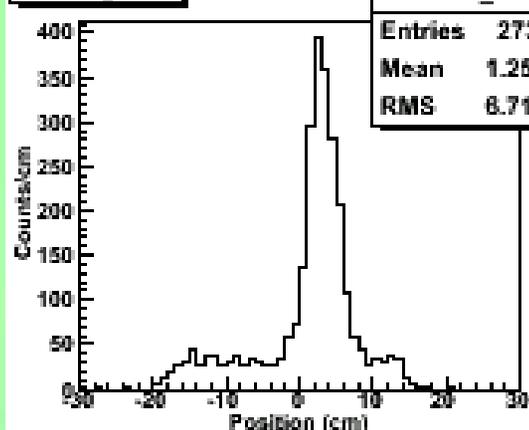
sBAR4_POS



Bar number
sBAR4_POS
Entries 3031
Mean 4.069
RMS 7.069

Bar 4
plane X

sBAR18_POS



sBAR18_POS
Entries 2731
Mean 1.256
RMS 6.712

Bar 3
plane Z

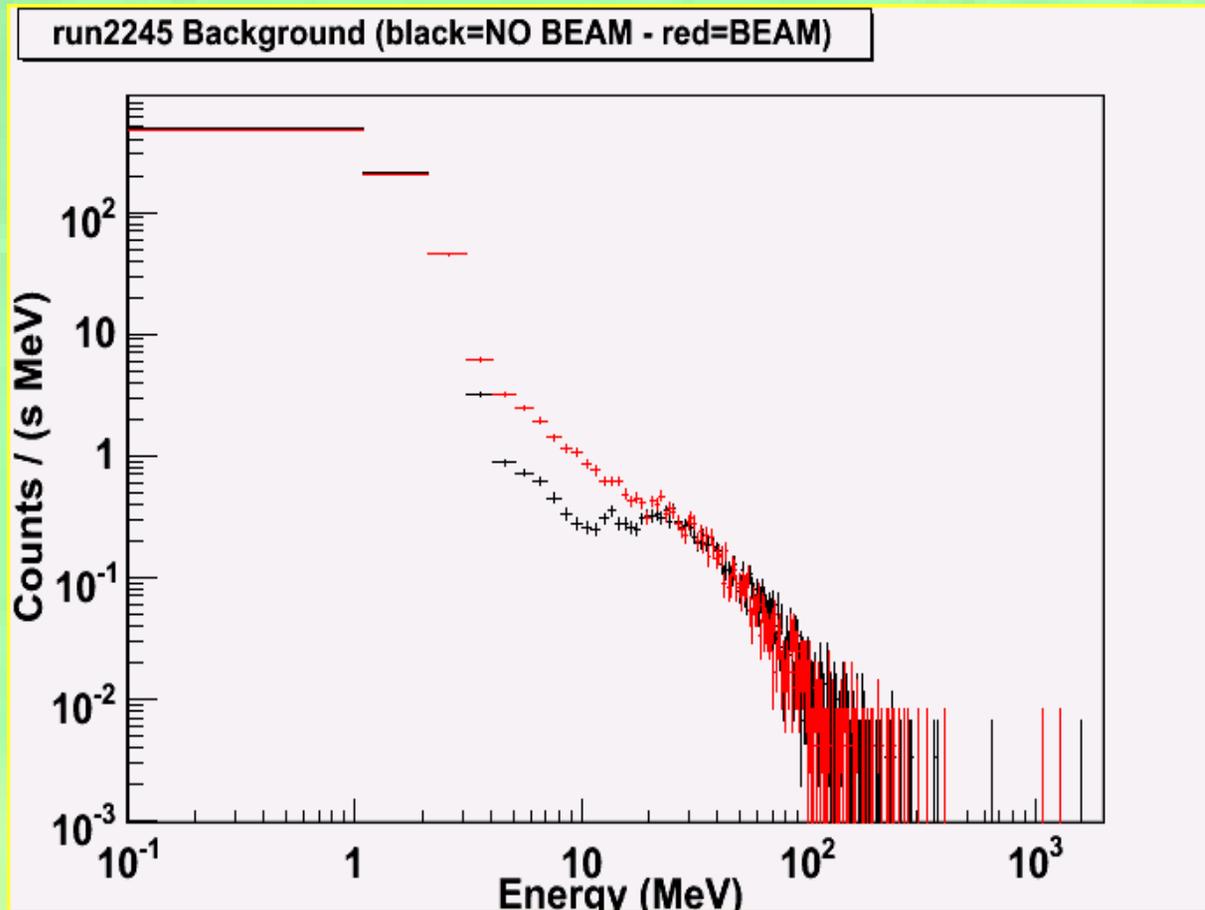
AGILE LNL-BTF run no. 2245

E beam 450 MeV
(30.09)

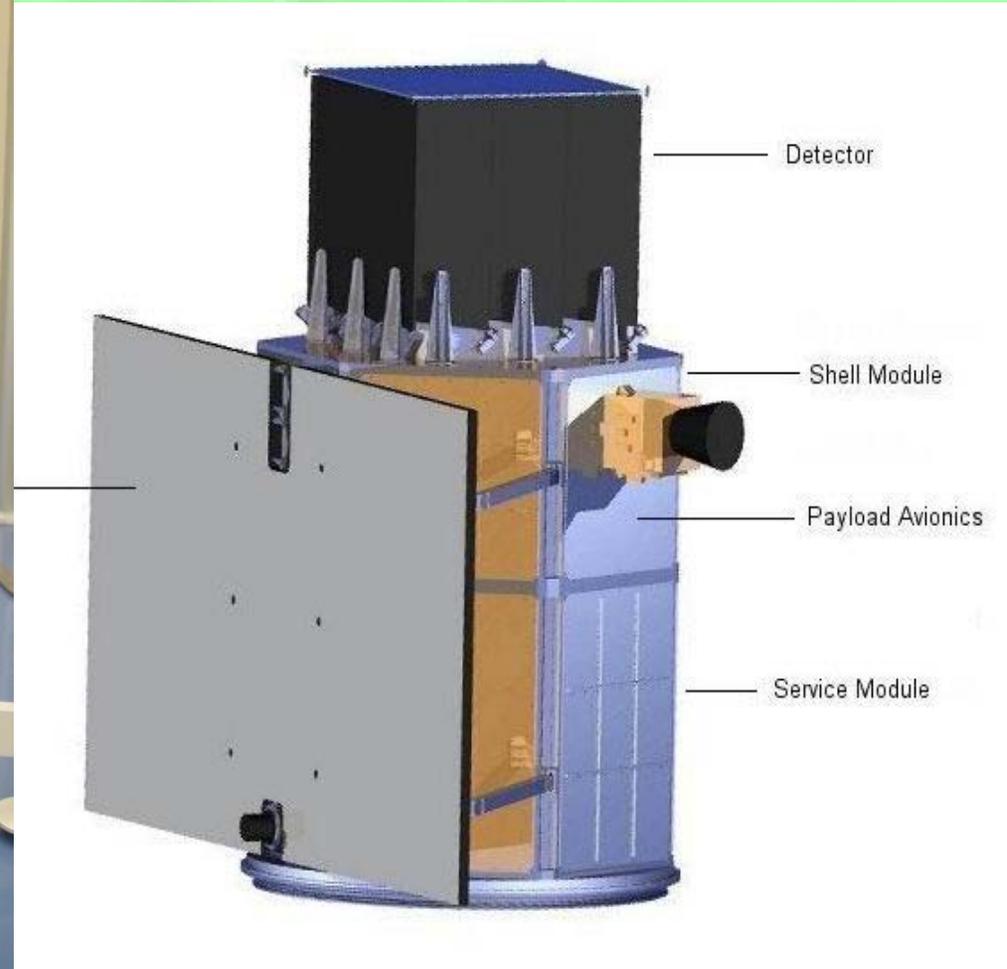
beam on AGILE at (13, 523.01), $\theta = 30^\circ$ $\varphi=135^\circ$

MCAL Burst mode

MCAL preliminary spectra (on-off beam)



We are ready !



**AGILE Satellite Flight Model
(CGS, Tortona, mid-December 2005)**

Current Mission Schedule

- Payload AIV: June-October 2005
- Instrument gamma-ray calibration at LNF-BTF: November 2005
- P/L finalization after satellite-system tests: end of Jan. 2006
- Satellite pre-integration tests: Dec. 2005
- Satellite integration, test and qualification at IABG (Munich): January-March 2006
- **AGILE launch campaign: September-October 2006**
- **AGILE in-flight commissioning: October-November 2006**
- **Start of AGILE scientific operations: December 2006**

The launcher : PLSV



Launch by the
**Indian Space
Research
Organization**

Low Equatorial
Orbit

(h=**550 km**, $i \sim 0^\circ$)

The End

Scientific Team web sites:

[http:// agile.rm.iasf.cnr.it](http://agile.rm.iasf.cnr.it)

[http:// agile.iasf-milano.inaf.it](http://agile.iasf-milano.inaf.it)